Canada Mortgage and Housing Corporation
Société canadienne d'hypothèques et de logement

CMHC Helping to house Canadians

STUDY OF FLUE, FURNACE AND ENVELOPE PARAMETERS AFFECTING OIL FURNACE START-UP SPILLAGE

FILE: 7218,DD#71

FEBRUARY 18, 1988

G.K. Yuill & Associates Ltd.
Consulting Engineers

FILE: 7218,DD#71

FEBRUARY 19, 1988

Mr. Don Fugler
CANADA MORTGAGE AND HOUSING CORPORATION
National Office
682 Montreal Road
OTTAWA, Ontario
K1A OP7

Dear Mr. Fugler:

Attached please find our final report on the "Study of Flue, Furnace and Envelope Parameters Affecting Oil Furnace Start-Up Spillage."

Sincerely,

G. K. YUILL AND ASSOCIATES LTD.

A. Lemoine

for G. K. Yuill, Ph.D.,P.Eng.

:al

Attach.

COPYRIGHT - CMHC 1987

1441 PEMBINA HWY., WINNIPEG, MANITOBA R3T 2C4 • (204) 474-2461 • FAX: (204) 453-0691

STUDY OF FLUE, FURNACE AND ENVELOPE PARAMETERS AFFECTING OIL FURNACE START-UP SPILLAGE

FILE: 7218,DD#71

PREPARED BY:

G. K. YUILL AND ASSOCIATES LTD.
1441 Pembina Highway
WINNIPEG, Manitoba
R3T 2C4

FEBRUARY 18, 1988

TABLE OF CONTENTS

1.0	EXECUTIVE SUMMARY	1
2.0	EFFECTS OF FLUE PARAMETERS	4
2.1	Introduction and Summary	4
2.2	Flue Location	5
2.3	Diameter	6
2.3.1	Spillage after a Cold Backdraft	7
2.3.2	Time to Backdraft after a Cold Equilibrium	8
2.4	Flue Thermal Inertia	8
2.5	Flue Insulation	9
2.5.1	Insulation Effects in Backdraft Situations	10
2.6	Chimney Length	10
2.6.1	Length Effects in Backdraft Situations	11
3.0	EFFECTS OF FURNACE PARAMETERS	12
3.1	Introduction and Summary	12
3.2	Furnace Tuning	13
3.3	Barometric Damper Location	14
3.4	Size of Combustion Chamber and Heat Exchanger	15
3.5	Steady-State Stack Gas Temperature	15
3.6	Vent Connector Insulation	16
3.7	Draft-Inducing Fan	16
4.0	EFFECTS OF ENVELOPE PARAMETERS	18
4.1	Introduction and Summary	18
4.2	Fresh-Air Intake	18
4.3	Ambient Temperature	20

4.4 Length of Chimney Extending Above the Roof 20

4.5 Houses with Fireplaces 20

5.0 HEIGHT OF CHIMNEY CONDENSATION 21

5.1 Introduction 21

5.2 Flue Location 21

5.3 Flue Diameter 22

5.3.1 Standard A-Vents 22
5.3.2 Oversized Masonry Chimneys 22

5.4 Flue Thermal Inertia 23

5.5 Flue Insulation 23

5.6 Flue Length 24

5.7 Limitations of FLUESIM Version 3.0 25

FIGURES

APPENDIX: Specifications of the Furnace Used and the Standard 127-mm Flue and Flue Pipe

1.0 EXECUTIVE SUMMARY

This report summarizes a study of flue, furnace and envelope parameters that can affect start-up spillage of an oil furnace. The transient furnace-flue system performance after firing was simulated using the heating system simulation program FLUESIM. As a basis of comparison, this study uses a 127-mm or 5" standard A-Vent, which is specified in detail in the Appendix. Every parameter was compared to this standard system at various degrees of backpressure during a start up after a cold equilibrium. The effect of different house backpressures is shown for the 127 mm standard furnace system in Figure 1.

Unlike gas furnaces, oil furnaces can easily overcome standby backdrafts. Therefore, houses equipped with an oil-heating system do not encounter continuous spillage. Start-up spillage, however, occurs regularly and can be quite prolonged with small chimneys or poorly maintained furnaces.

This study concentrates on the time it takes the flue to overcome initial spillage under a number of different conditions and came to the following conclusions:

a) An interior flue performs better during start up than the same size exterior flue.

b) A decrease in flue size below normal greatly increases the time needed to overcome spillage, whereas an increase above normal has a much smaller effect in the opposite direction.

c) Oversized clay-lined masonry flues perform worse than large A-vents. An increase in the size of large clay-lined flues will actually increase spillage time.

d) After an induced backdraft of 4 Pa back pressure, oil furnaces reverse flue flow to upwards immediately after firing. Spillage is generally only slightly longer than after starting from equilibrium at 0 Pa.

e) A small flue backdrafts marginally sooner after shutting down at hot equilibrium than a larger flue.

f) Flue thermal inertia does not significantly change start-up spillage and therefore should not be considered a design parameter.

g) Flue insulation has little effect on start-up spillage after equilibrium at 0 Pa.

h) Insulated flues will take much longer to backdraft after shut down at hot equilibrium.

i) For low depressurizations, a short flue performs best. However in houses where high backpressures occur, a longer flue is desirable.

j) The furnace-flue system operates better during start up if the fuel is burned with less excess air.

k) An increase in reverse flow opening area of the barometric damper increases the amount of spilled gas proportionally. However, it does not have an effect on the length of time over which the spillage occurs.

l) A lower position for the barometric damper improves start-up flue performance significantly.

m) The size of the combustion chamber and heat exchanger have no effect on start-up spillage.

n) An increase in stack gas temperature decreases start-up spillage although it also decreases furnace efficiency.

o) The degree of insulation of the vent connector has no effect on start-up spillage.

p) Installing a draft-inducing fan very effectively reduces or even eliminates start-up spillage.

q) An increase in the area of fresh-air intake has a decreasing effect on fan-induced house backpressure, therefore improving start-up performance.

r) As expected, spillage is much less at lower ambient temperatures.

The last part of this study investigates the time and height extent of flue condensation for different flue parameters and comes to the following conclusions:

s) Interior flues exhibit less condensation than exterior flues, other things being equal.

t) Larger flues have slightly more condensation. Oversized masonry chimneys have much more condensation than smaller flues.

u) Large thermal inertia of the flue liner increases condensation of the flue gas.

v) Flue insulation has little effect on chimney condensation.

The following four chapters describe in detail the study concerning start-up performance and flue condensation of oil furnace and flue systems.

2.0 EFFECTS OF FLUE PARAMETERS

2.1 Introduction and Summary

To investigate the duration and amount of spillage, FLUESIM was used to simulate the transient behavior of furnace-flue systems for various flue locations, diameters, lengths, insulation and thermal masses under different house backpressures. The starting condition for all simulations was either a cold equilibrium with no house depressurization or a 4 Pa induced cold backdraft. This assumption is reasonable, because a cold equilibrium is the most critical condition for start-up spillage, and realistic, because in most houses the off-period is long enough to allow the flue to cool to a cold steady state.

In each case the exhaust fans, which generate house backpressure, were turned on with the furnace. The analysis of the FLUESIM results indicates the following:

a) Interior flues perform better than equivalent exterior flues under the same conditions.

b) Decreasing the flue size below normal significantly increases the time needed to overcome start-up spillage. However, increasing it has a much smaller effect in the opposite direction.

c) Oversized clay-lined masonry flues perform worse than large A-vents. An increase in the size of large clay-lined flues will actually increase spillage time.

d) After an induced backdraft of 4 Pa back pressure, oil furnaces reverse flue flow to upwards immediately after firing. Spillage is generally only slightly longer than after a 0 Pa equilibrium.

e) A small flue backdrafts marginally sooner after a shutdown at hot equilibrium than a larger flue.

f) Flue thermal inertia does not have a significant effect on start-up spillage from equilibrium and should not be considered in flue design.

g) Flue insulation has little effect on start-up spillage after a 0 Pa equilibrium.

h) Insulated flues will take much longer to backdraft after shut down at hot equilibrium.

i) At low backpressures a short flue performs best, whereas at high backpressures, a longer flue produces less spillage.

A detailed analysis of the effects is presented in the following four sections.

2.2 Flue Location

To compare flue performance of interior vs. exterior flues, the 127-mm A-vent as given in the Appendix was used with an oil furnace, which is also specified in detail in the Appendix. The time needed to overcome start-up spillage was measured for house depressurizations of 0 Pa, 4 Pa, 7 Pa and 10 Pa, and is plotted in Figure 18.

The performance of the interior flue is marginally better (about 10% time reduction), which is due to higher liner and flue gas temperatures at equilibrium. These higher temperatures correspond to higher thermal energy of the flue-gas column, and thus create a larger flue draft. This enables the interior flue to overcome initial spillage faster than the exterior chimney.

Since a house is only heated at lower ambient temperatures and the temperature differential drives flue draft, an interior chimney is preferred.

2.3 A-Vent Diameter

To determine the effect of the diameter on start-up spillage, three exterior A-vents and two exterior clay-lined masonry chimneys were considered. The A-vents had minimal sizes of 127 mm, 152 mm, and 178 mm, whereas the masonry chimneys were oversized with square dimensions of 203 mm and 241 mm.

The start-up spillage was analyzed for a range of house depressurizations from 0 Pa to 10 Pa. The three A-vents were additionally tested for depressurizations up to 23 Pa and are compared in Figure 5. Since dilution flow is equal to flue flow minus furnace flow, the time integrated area above the flue flow curves and below the furnace flow curves in Figures 2, 3 and 4 represents the total amount of spilled gas. This indicates that the smaller A-vents perform worse both in terms of spillage time as well as in terms of amount of spilled gas.

As expected, increasing the flue diameter greatly improves start-up performance of the flue-furnace system. However, as the comparison of only three flue sizes shows, an indefinite increase in diameter will not continue to improve start-up performance. As can be seen in Figure 5, an increase from 127 mm to 152 mm decreases the time to overcome spillage by an average of over 50%, whereas an increase to 178 mm results in an improvement of only an additional 10 - 20%. This leads to the conclusion that a decrease of diameter below normal greatly increases the time to overcome start-up spillage, whereas increasing it above normal decreases time to overcome spillage only slightly.

To show the performance of oversized clay-lined flues in comparison to the three A-vents, all five exterior flues are plotted in Figure 20. Although the masonry flues have a larger cross section than the largest A-vent, the two masonry flues do not perform better. Their performance consistently falls between the 127-mm and the 152-mm A-vent.

Figure 20, in fact, leads to the conclusion that an indefinite increase in flue size will actually result in a decrease in flue performance. The 241-mm square masonry flue will spill exhaust gas about 10 - 20% longer than the 203-mm flue.

Although one cannot compare the oversized masonry chimneys directly to the A-vents, sizing effects should yield similar results for both. Therefore, the conclusion that size increase will not indefinitely improve flue performance is reasonable, although it is not proven directly.

Spillage, at least with the larger size flues, occurs only in the first minute after firing under reasonable depressurization levels (0 - 10 Pa). Assuming that the furnace room air is not mixed rapidly with the rest of the air in the house, the spillage will soon be removed from the furnace room as combustion or dilution air. Therefore, the small amount of start-up spillage which occurs with the larger size flues will not contribute significantly to indoor pollution.

An increase in flue cross-sectional area increases chimney flow proportionally at stand-by and also during a run. The chimney flow, however, represents the total air flow out of the house, thus contributing to house cooling. Since larger flues remove air at a higher rate, they will cool the house more. This trade-off between less start-up spillage and increased cooling effect suggests a compromise in flue diameter. To determine the quantitative effect of the flue size on house cooling is beyond the scope of this study.

2.3.1 Spillage after a Cold Backdraft

To study flue performance after backdrafting occurred at standby, a fan flow rate of 82.8 L/s resulting in a 4 Pa depressurization was used in the FLUESIM input file. Runs were performed until an off-cycle equilibrium was reached at which backdrafting occurred. All three A-vents showed stand-by backdrafting under these conditions. However,

upon firing of the furnace, all flues overcame backdrafting immediately due to the action of the furnace blower.

The immediate reinstatement of upward flue flow results in spillage time that is only slightly longer than after a start without backdrafting. Figure 21 shows that spillage time is less than twice as long after a 4 Pa backdraft for the smaller flues and about four times as long for the 178-mm A-vent. In all cases, spillage time after a 4 Pa backdraft is less than 15 seconds longer than after a 0 Pa equilibrium.

Since oil furnaces overcome backdraft immediately after firing, and spillage is not a great deal longer than after a 0 Pa equilibrium, chimney backdrafting is not a serious problem as it is with gas furnaces.

2.3.2 Time to Backdraft after a Hot Equilibrium

To study the effect of flue diameter on the time it takes a flue to backdraft two sizes, 127 mm and 152 mm were considered. The furnace was run until the system reached a hot equilibrium and then turned off. At a low depressurization level of 4 Pa, both flues showed no backdrafting after one hour. However, as expected, the higher the house depressurization, the sooner the flue backdrafts.

Figure 22 shows that the larger flue performs marginally better due to the higher initial draft when the flue liner is hot.

2.4 Flue Thermal Inertia

To determine the effects of flue thermal inertia on the duration of start-up spillage, five flues were considered: three variously insulated A-Vents and two masonry chimneys with .3-mm and 1.2-mm metal liners, all flues having a 127-mm diameter. The furnace-flue systems were exposed to house backpressures ranging from 0 to 10 Pa. The only starting condition used was a cold equilibrium, because this is the most critical condition for start-up spillage.

The behavior of the various flues at start up is shown in Figures 6, 7 and 8. As can be seen, the performance at start up shows little difference for the different flues. The heavier lined masonry chimney needs slightly longer to overcome spillage due to a slower heat up of the liner. The close agreement between the flue performances is not surprising since the flues have similar liner and flue gas temperature at start up.

Over several short on-off cycles, the heavier lined flues will perform better, because they retain their heat longer and therefore can provide better draft during start-up. As stated above, however, most spillage occurs at start-up after cold equilibrium. Since in most houses off periods are long enough for the flue to cool to equilibrium, and thermal inertia does not significantly effect flue performance in that case, it should not be considered as a design parameter.

2.5 Flue Insulation

To determine if start-up spillage depends on the level of flue insulation, three different flues were simulated: one B-vent with a 1/2" air space, and two A-vents insulated with fiberglass to values of RSI 1 and RSI 2. All vents had an inner diameter of 152 mm.

From an equilibrium obtained at 0 Pa house depressurization, the three flues performed very similarly. The variations in time to overcome spillage were less than 5% over a depressurization range from 0 to 10 Pa, when exhaust fans were turned on at furnace start-up (Figure 23).

2.5.1 Insulation Effect in Backdraft Situations

Flue insulation, however, has an effect on flue performance in situations when backdrafting can occur. When the time to backdraft after a hot equilibrium at 7 Pa and 10 Pa depressurization is calculated, the more insulated flue (RSI 2) performs much better

(approximately 2.5 times longer to backdraft) than the uninsulated B-vent (See Figure 24).

This improvement of performance by increasing insulation is due to the ability of an insulated flue to retains its liner and gas-column temperature longer. Insulating the flue will have a positive effect on performance in both short and long on-off cycles (unlike the effect of flue thermal inertia, Section 2.4). An insulated flue will have a higher cold equilibrium temperature and thus create more draft after furnace start up. The insulated flue will also retain its heat longer during the off-cycle and thus backdraft less.

An analysis of the mean flue gas and mean flue liner temperature for the first 52 sec shows that the insulated flues have a higher stand-by temperature but warm up more slowly, due to the extra thermal mass of the insulating material. Therefore, the better performance of an insulated chimney in short on-off cycles is due to a higher cold-equilibrium temperature, not due to a faster warm up, as it is in the case for a low thermal inertia flue.

This analysis also leads to the conclusion that the insulated flues will give less spillage under low depressurization and more spillage under high depressurization than the B-vent. This trend becomes apparent in Figure 23.

2.6 Chimney Length

To determine the effect of chimney length on start-up flue performance, three 127-mm A-vents were simulated. The lengths were 5.00 m, 7.50 m, and 10.00 m. House backpressures ranged from 0 Pa to 12 Pa for each chimney. The results are shown in Figure 16 as a plot of time to overcome spillage vs. house backpressure.

The result of this study does not favor a particular flue over the entire depressurization range. At low backpressures, the shorter flue performs best. This is for two reasons. First, the standby chimney

flow is larger in the shorter flue doe to less friction losses and secondly, the shorter flue gas column in the short flue can respond faster to changing furnace flow rates after firing. However, the shorter flue produces less draft than a longer one, thus its performance is only better under low backpressure levels where less draft is required.

Increasing the flue length to 10.0 m improves flue performance during start-up at high depressurizations, where more draft is required. High depressurization results in a fairly long time to overcome spillage for all flue lengths. This time is sufficient for the long flue to overcome the inertia effect of its long gas column. Then the effect of the increased draft will predominate and favor the longer flue.

This differentiation between performance at low or high backpressures makes it necessary to design flue length according to depressurization levels usually occurring in the house. If high levels of depressurization are common, a long flue is the better design; if only low depressurizations occur, a short flue is desirable.

2.6.1 Length Effects in Backdraft Situations

As in Section 2.3.1, the flue performance was tested after a 4 Pa induced backdraft has occurred. This was then compared to the performance after a 0 Pa cold equilibrium.

As expected, all flues perform worse after a backdraft (see Figure 25). The 4 Pa backdraft resulted in an approximately 15 second longer spillage time for all lengths.

As in the case of no initial backdrafting, the 10.0 m flue performs worse than the shorter flues.

3.0 EFFECTS OF FURNACE PARAMETERS

3.1 Introduction and Summary

To investigate dependency of flue performance on furnace parameters, a 127-mm A-Vent was used with differently-tuned furnace burners and barometric dampers. A FLUESIM simulation was run for each case and time to overcome spillage as well as amount of spillage were monitored. Additional simulations included an insulated vent connector and a draft-inducing fan.

The following six sections analyze the findings in detail. As a summary it can be stated that

a) the furnace-flue system performs best during start up if the fuel is burned with a minimum of excess air,

b) increasing the reverse flow opening area of the barometric damper has no effect on the time required to overcome spillage, but increases the amount of spilled gas proportionally,

c) a lower position for the barometric damper improves start-up performance significantly,

d) An increase in stack temperature reduces spillage, but also decreases furnace efficiency,

e) The size of heat exchanger and combustion chamber, as well as the insulation of the vent connector pipe have no influence on start-up spillage,

f) a draft-inducing fan, installed downstream of the barometric damper, is very effective in reducing or even eliminating start-up spillage.

3.2 Furnace Tuning

Assuming a relatively new furnace with a constant firing rate, tuning of an oil furnace is comprised of two tasks: adjusting the combustion air and balancing the barometric damper.

The amount of combustion air is expressed as % excess air with 0% excess air being the stoichiometric amount. The ability to overcome start-up spillage was tested for furnaces that were tuned to burn with 0%, 50% and 100% excess air. Again, the furnaces were fired after cold equilibrium at 0, 4 Pa and 7 Pa backpressure. The results are presented in Figure 9.

The quite significant effect of the amount of excess air on flue performance is due to two causes. First, the increased amount of air going through the furnace will naturally increase furnace flow at a constant firing rate. Secondly, an increased amount of combustion air has to be heated by the burner. This, of course, results in a lower combustion gas temperature, which results in a decrease in draft. Combining these two effects increases spillage.

Because of the two reasons described above, a furnace-flue system would perform best at start-up if the fuel is burned with stoichiometric air. However, to ensure complete combustion, a higher excess air level is desirable.

The second parameter concerning furnace tuning is the balancing of the barometric damper. A poorly balanced barometric damper will not close under reverse dilution flow conditions. To determine the quantitative effect of barometric damper balancing, three different reverse-flow open areas were studied. These were 5%, 10%, and 20% of fully open area. The results are shown in Figures 10 and 11, where flow rates are plotted vs. time, for 4 Pa and 7 Pa backpressures.

As expected, the larger the reverse flow open area the more spillage occurs. Somewhat surprising however, it takes exactly the same

length of time to overcome spillage for all three barometric dampers. This could be explained as follows: the initial furnace flow and flue flow rates are the same for all barometric dampers. After firing, the furnace flow rate is still the same for all and the flue flow rate is only slightly less for the worse balanced dampers. Therefore, most of the combustion products (approximately 75 - 85%) flow up the chimney and increase flue flow. The same initial flow rates and (almost) the same increase in flue flow will result in the same time needed to overcome spillage for all three barometric dampers.

An important result of this part of the study is that although the time to overcome spillage is the same, the amount of spilled gas varies almost proportionally to the % reverse flow opening area.

As an ideal case, a reverse flow opening of zero would result in no spillage. Practically this can be accomplished, but a simulation using FLUESIM is limited to at least a 5% opening.

The very significant effects of both the excess air and the reverse flow opening of the barometric damper on the start-up performance of the furnace-flue system indicate that a properly tuned furnace (low excess air and small reverse flow damper opening) is essential to ensure a good start-up performance of the heating system.

3.3 Barometric Damper Location

Two locations of the barometric damper were considered in this study. The dampers were located .205 m above and below the furnace exit pipe. A time to overcome spillage vs. house backpressure comparison of the two cases is presented in Figure 17.

The difference in start-up performance is quite pronounced. Flue performance is about 40% better for the lower barometric damper. This is due to the fact that, in order to escape out the damper, the combustion gas has to flow downwards, against its natural buoyancy. This results in less time over which spillage can occur.

The result, that a lower installed barometric damper will improve performance, suggests this remedial measure: instead of the barometric damper being attached directly to the vent connector, it could be connected via a pipe that extends downward from the vent connector. This would lower the damper and thus decrease time to overcome start-up spillage.

3.4 Size of Combustion Chamber and Heat Exchanger

To test the effects of combustion chamber and heat exchanger size, five cases were studied at 4 Pa house depressurization: a .7 m^3 combustion chamber with 50 Kg, 61 Kg, and 75 Kg heat exchanger plus the 61 Kg heat exchanger with a .5 m^3 and a 1.0 m^3 chamber.

The results obtained from these cases were that neither of the parameters had an effect on start-up spillage. The five furnaces behaved very similar and therefore the size of the combustion chamber and heat exchanger should not be considered a design parameter.

As in the case of different flue thermal inertia, a heavier heat exchanger would perform better in short on-off cycles, because it retains its heat longer. However, in the critical case of firing after a cold equilibrium period, it does not reduce spillage.

3.5 Steady-State Stack Gas Temperature

The stack gas temperature is measured at the exit of the oil furnace when the combustion gas enters the vent connector. Although steady-state temperature depends on various furnace parameters, this study assumes that the steady-state stack gas temperature can be controlled without stating how it is affected. For the purpose of determining the effect of a different stack gas temperature on start-up spillage, temperatures of 200 °C, 240 °C and 300 °C were selected. The results are shown in Figure 19.

Whereas the flue behavior is very similar for all cases during the first five seconds, it starts to deviate rapidly after that. At a higher stack gas temperature the flue is able to overcome spillage much faster. This is due to a higher flue gas temperature and thus a higher buoyancy of the flue gas column.

On the other hand, higher stack gas temperature means a lower furnace efficiency, if it is obtained by decreasing the heat exchanger capacity, because more heat is lost through the chimney. Therefore achieving a higher stack gas temperature by this means is not desirable. On the other hand, increasing stack gas temperature by keeping the excess air as low as possible will reduce spillage both because of the increased temperature and the decreased flow. Of course, complete combustion must be maintained.

3.6 Vent Connector Insulation

To study the effect of insulating the vent connector, the vent connector of the furnace-flue system described in the Appendix was replaced with a double-walled insulated one. The insulation was 127-mm thick with an outer metal liner of .3 mm.

The FLUESIM simulation showed no difference between the behavior of the flue in this case compared to the non-insulated case. All data obtained at start-up after a cold equilibrium were exactly the same and therefore the insulation of the vent connector should not be considered in the design of the furnace-flue system.

3.7 Draft Inducing Fan

A draft-inducing fan can be installed downstream of the barometric damper in the vent connector. It creates a draft in addition to the flue draft in order to increase dilution flow. In testing flue performance with and without a draft-inducing fan, backpressures from 4 to 23 Pa were applied. Since spillage with the draft-inducing fan only

occurred at 23 Pa, a graphical comparison is only shown for this backpressure in Figure 12.

House depressurizations of over 10 Pa are generally not encountered even in a very airtight house. Therefore it is reasonable to assume that when a draft-inducing fan is installed with an oil furnace, spillage will not occur, provided, of course, the furnace is properly tuned as described in Section 3.2.

4.0 EFFECTS OF ENVELOPE PARAMETERS

4.1 Introduction and Summary

The envelope parameters considered in this study were size of fresh air intake, ambient temperature and fireplace parameters. Three different air intake ducts and four temperatures were used in the FLUESIM transient analysis of the 127-mm A-Vent. The various fresh air intake sizes had an effect on fan depressurization before and during furnace operation. This made it necessary to differentiate between effects at constant backpressure and effects at a constant exhaust fan flow rate.

The analysis described in the following sections leads to these conclusions:

1) The size of the fresh air intake has little effect on flue performance, at a constant house depressurization. As expected, however, it has a significant effect at a constant fan flow rate. Generally increasing the fresh air intake improves transient performance.

2) The flue-furnace system operates with much less start-up spillage at lower ambient temperatures.

3) Fireplaces have the same effect on flue performance as an exhaust fan of the same flow capacity.

4.2 Fresh Air Intake

A fresh air intake is an opening in a wall of a house to allow ambient air to enter with negligible resistance. It could be placed anywhere in the house, but is generally situated in the furnace room. The fresh air intake can be considered as a passive means of make-up air supply. It decreases the exhaust fan-induced house backpressure slightly, because it increases the envelope equivalent leakage area and thus the envelope flow coefficient.

To determine the effect of different intake sizes on the start-up performance of the furnace-flue system, three different fresh air intakes were considered. They were 0.0, 0.0177 m^2 and 0.0324 m^2 in cross-sectional area, all at the same height below chimney top and they all had one elbow. The three situations were simulated at approximately 0, 4 Pa and 7 Pa house depressurizations and the results are shown in Figure 13. House backpressure levels could only be approximately selected and varied for the three intake ducts, because for a constant exhaust fan flow changing the fresh air intake area will change the depressurization of the envelope. The same results, plotted against exhaust fan flow rate instead of backpressure are shown in Figure 14.

As expected, a larger air intake duct substantially improves flue performance for a constant fan flow rate. This is mainly due to the fact that the larger duct decreases the resultant house backpressure. For example, whereas a fan flow rate of 136.3 L/s results in a depressurization of 8.6 Pa in a house without a fresh air intake, it only causes a 5.2 Pa backpressure in the same house equipped with a large .0324 m^2 air duct.

If the time to overcome spillage is now plotted vs. house depressurization, as in Figure 13, the effect of fresh air duct size is much smaller. However, in a realistic case the independent variable is not the depressurization, but the exhaust fan flow rate. Therefore, Figure 14 is the more important result and it indicates that he size of the fresh air intake is significant for flue performance during start-up.

As it was the case for flue diameter, an indefinite increase in fresh air intake size will not continue to improve flue performance. An intake duct that is too large will increase the standby flue flow and cool off the furnace room, thus decreasing flue draft. This analysis shows, however, that a fresh air intake of appreciable size should be included in the envelope-furnace-flue system design.

4.3 Ambient Temperature

The primary temperature range for operation of a heating system in Canada is from about -30°C to +10°C. The simulations were carried out at -30°C, -15°C, 0°C and 10°C with backpressures of 0 Pa, 4 Pa, 7 Pa, and 10 Pa for each temperature.

The results are summarized in Figure 15, which plots time to overcome spillage vs. fan depressurization. As expected, the furnace-flue system performs much better at low temperatures, because the flue draft increases with decreasing ambient air temperature.

4.4 Length of Chimney Extending Above the Roof

In this part of the study, the length of the chimney extending above the roof was varied from 1.0 m to 3.0 m without changing the overall chimney length. The study was carried out for an interior as well as the exterior chimney at 4 Pa house backpressure.

In both cases, the variation of the length that extends above the roof had no effect on the time to overcome spillage. The expected result would be that, for an interior chimney, changing the length above the roof would affect flue performance because it changes the mean flue liner and gas temperature. However, this effect would only be small and obtained only for large variations in the length above the roof. It would be unrealistic to assume that a chimney of a house extends more than 3.0 m above its roof. Therefore, this study concludes that the length a chimney extends beyond the roof is not a design parameter.

4.5 Houses with Fireplaces

The effect of a fireplace on flue performance depends only on the rate it removes air from the house. In FLUESIM, a fireplace is specified by its maximum flow rate only, and therefore has exactly the same effect as an exhaust fan of the same flow capacity. A separate analysis for different fireplaces will therefore not be included in this report.

5.0 HEIGHT OF CHIMNEY CONDENSATION

5.1 Introduction

This chapter focuses on the height and time extent of chimney condensation for various flue parameters. The condensation was monitored for the different simulation runs at the highest depressurization (generally 7 Pa or 10 Pa) that the particular variable was tested. This was necessary because no new run were done for this part of the study and the best data available (i.e. the longest run) was at the highest depressurization level.

The effect of depressurization level on the height and time extent of chimney condensation was found to be negligible in the range of 0 - 10 Pa.

Condensation of the flue gas occurs if the liner temperature is below the dew point of the flue gas at the height in question. Therefore, flues with higher initial liner temperatures will show less condensation. The time extent of the condensation will also depend strongly on the thermal mass of the chimney. A thermally "lighter" chimney liner will warm up faster, thus reducing condensation time. The qualitative effects of this will be discussed in the following sections for various flue parameters.

The figures show the height of chimney condensation measured from the top as a percentage of total chimney height (7.50 m for all cases except in Section 5.6). This condensation height is plotted against the time from start-up during which it occurs.

5.2 Flue Location

As stated before, chimney condensation will be less if the initial liner temperature of the flue is higher or if the flue liner can warm up faster. An interior flue obviously has a warmer flue liner at standby

and therefore warms up through the dew point of the flue gas faster than the same extension flue.

This result is plotted in Figure 26. Condensation in the bottom half of the chimney (50% of chimney length) is shorter lived in the interior flue by about 25%.

Data for flue condensation of the interior flue above one half of the flue length was not available, since no new runs were made for this part of the study.

5.3 Flue Diameter

5.3.1 Standard A-Vents

Three standard A-vent sizes are 127 mm, 152 mm, and 178 mm inner diameter. At the same chimney length, these different diameters will result in a different total flue liner area. The larger flues have larger flue liner areas and thus will warm up slower, resulting in longer condensation time.

As Figure 27 shows, however, this time difference is very small. At a height of 50% flue length, water condenses in the 127-mm flue over approximately 5% less time than in the 152-mm flue, and about 10% less time than in the 178-mm flue.

5.3.2 Oversized Masonry Chimneys

The two large exterior masonry chimneys studied were square with inner side lengths of 203 mm and 241 mm. For similar reasons as in the case of the A-vents, the larger masonry flue performed worse than the smaller one.

When compared to the 178-mm interior A-vent, both masonry chimneys performed much worse (Figure 28). At about 3 minutes after firing, both

masonry vents will have condensation on about 3/4 of their entire length, whereas the A-vents will have overcome condensation.

This great difference is due to two reasons. First, both masonry flues were exterior, but the 178-mm A-vent was interior. As discussed in Section 5.2, interior flues show less condensation. Secondly, the masonry flues were clay lined, thus having a larger thermal inertia than the aluminum liner of the A-vent. As discussed in Section 5.4, larger thermal inertia will result in longer condensation time.

Therefore, the height and time extent of chimney condensation is a problem in large exterior clay-lined masonry flues. These flues are installed in a great number of older houses in North America. As will be seen in Section 5.4, the installation of a thinner metal flue liner will improve the condensation performance of masonry flues.

5.4 Flue Thermal Inertia

Three chimneys were studied to determine the effect of thermal inertia on chimney condensation. As expected, the flues with the lighter liners, ie. the masonry flue with an 0.3-mm metal liner and the A-vent performed better than the heavier 1.2-mm lined masonry flue.

As can be seen in Figure 29, the heavily-lined flue exhibits condensation about twice as long as the two lighter flues.

5.5 Flue Insulation

Three differently insulated 152-mm interior flues were monitored for condensation to determine the effect of flue insulation. Figure 30 shows that the height and time extent of flue gas condensation is very similar for all three flues. All chimneys had the same inner liner to eliminate the effect of thermal inertia of the flue liner.

The similarity between the different flues is due to a trade-off of two effects of the insulation: increasing the insulation results in less thermal conductance, but at the same time more thermal mass.

Less thermal conductance results in a higher cold equilibrium liner temperature which reduces condensation. However, larger thermal mass results in a slower warm up of the flue liner which increases condensation.

This reasoning is supported by the "crossing over" of the 3-vent-curve at times of about 50 sec. and 60 sec. At early times, the liner of the B-vent is cooler, thus resulting in a longer condensation time of the lower flue elements. At later times (after about 1 minute after firing), the B-vent has warmed up more than the insulated A-vents, resulting in shorter condensation times of the higher flue elements.

Therefore, flue insulation decreases the condensation time of the upper flue element but increases the condensation time of the lower elements.

5.6 Flue Length

Figure 31 shows the extent of chimney condensation for different flue lengths varying from 2.5 to 10.0 m.

If chimney condensation is plotted vs. percent of flue length as in Figure 1, the shorter flue performs better. This is obvious since the individual flue elements of the shorter flues are closer to the furnace and thus will warm up faster.

If, however, chimney condensation is plotted vs. actual height in meters as in Figure 32, it can be seen that condensation height decreases at the same rate for all flues.

5.7 Limitations of FLUESIM 3.0

FLUESIM Version 3.0 calculates the flue gas and flue liner temperatures for each time step. These temperatures are average temperatures over a "flue element", which is about 95 cm long for a 7.5-m flue. If the average flue liner temperature of a flue element is below the instantaneous dew point of the flue gas at that element, the program indicates that condensation will occur. Thus FLUESIM 3.0 does not give the exact height of condensation but rather indicates the lowest flue element that exhibits condensation. The locations of the flue elements are shown in Figure 33.

FIGURES

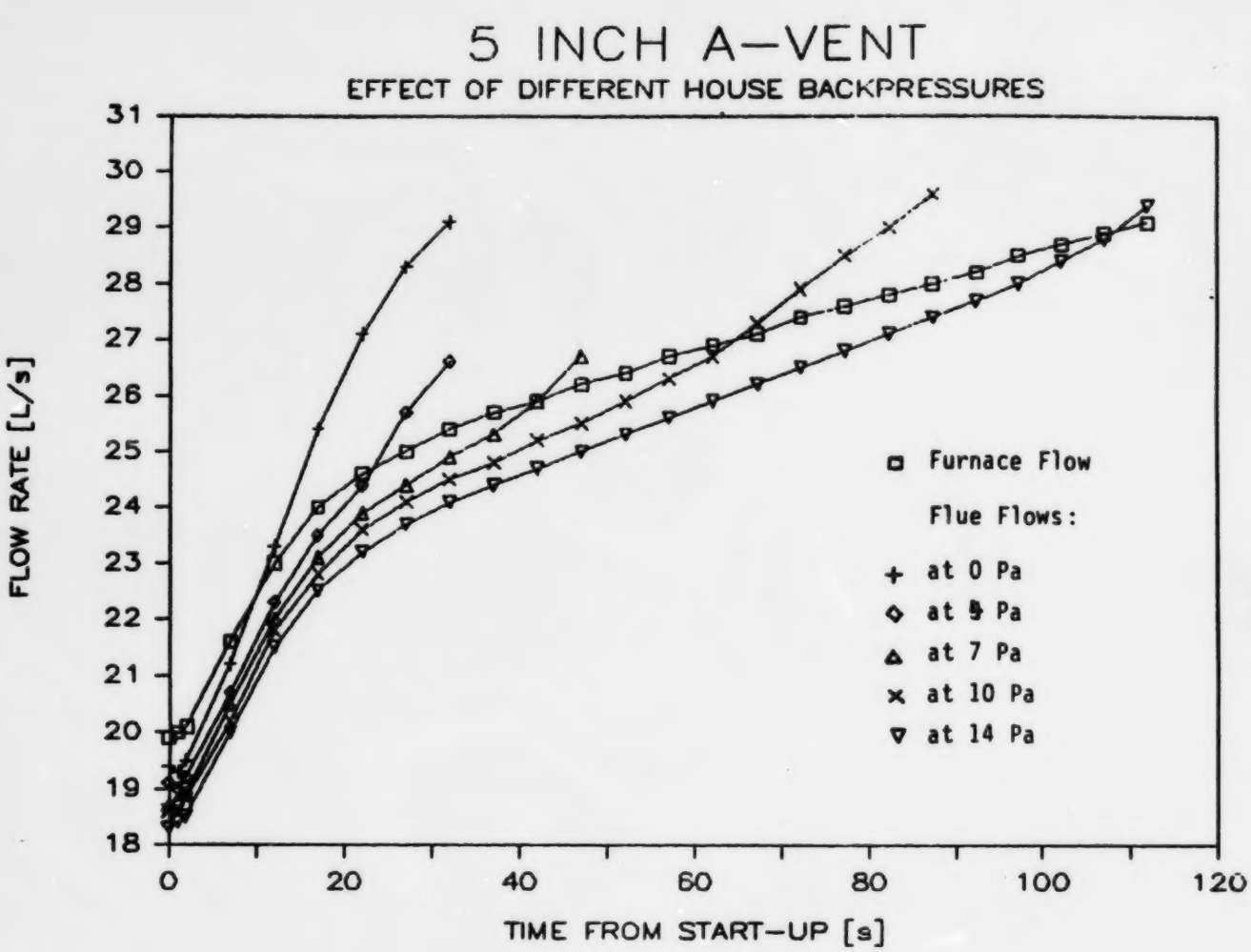

5 INCH A—VENT
EFFECT OF DIFFERENT HOUSE BACKPRESSURES
FLOW RATE [L/s]
31
30
29
28
27
26
25
24
23
22
21
20
19
18
0
20
40
60
80
100
120
TIME FROM START—UP [s]
Furnace Flow
Flue Flows:
at 0 Pa
at 5 Pa
at 7 Pa
at 10 Pa
at 14 Pa

Figure 1.

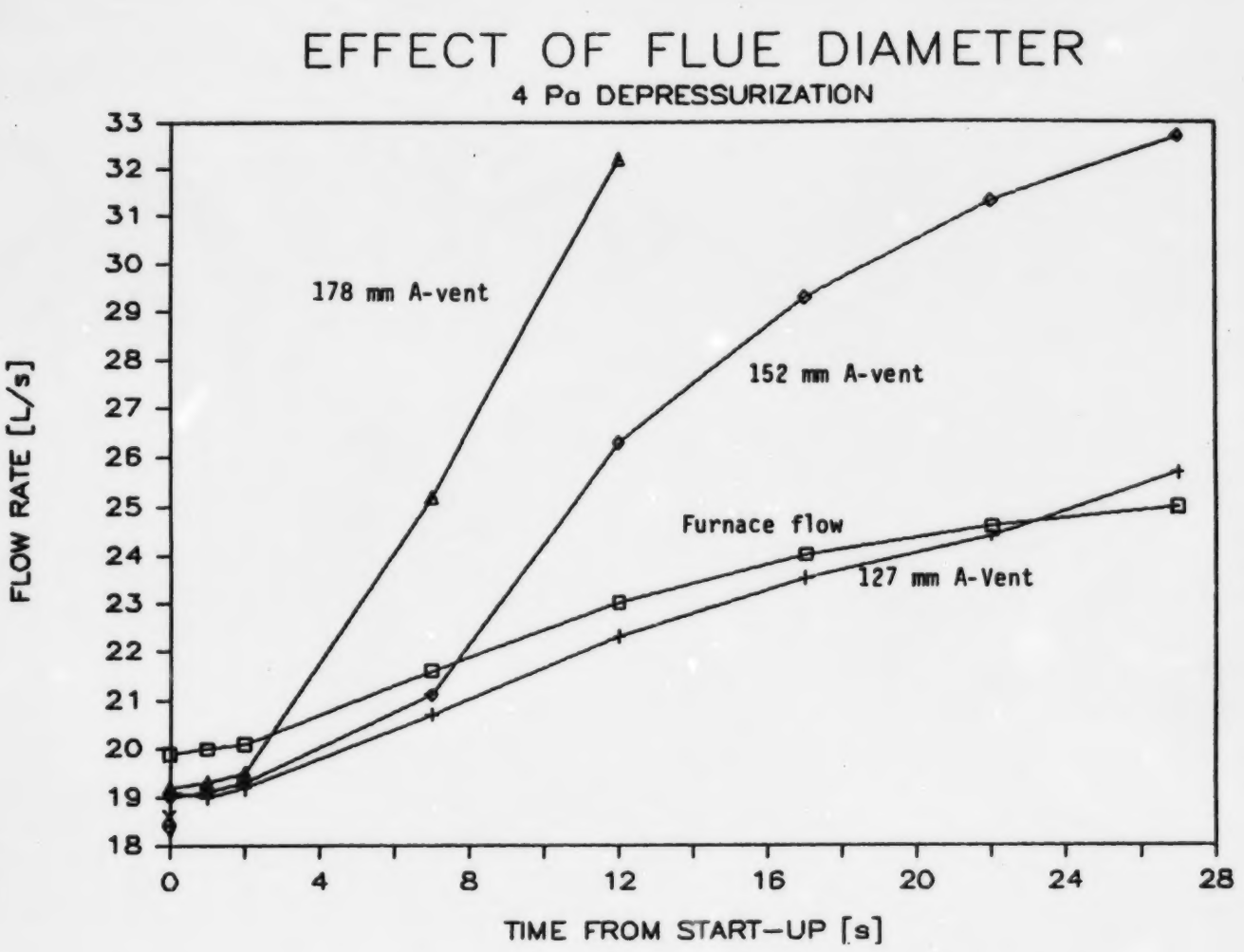

EFFECT OF FLUE DIAMETER
4 Pa DEPRESSURIZATION
FLOW RATE [L/s]
TIME FROM START-UP [s]
178 mm A-vent
152 mm A-vent
Furnace flow
127 mm A-Vent
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
0
4
8
12
16
20
24
28

Figure 2.

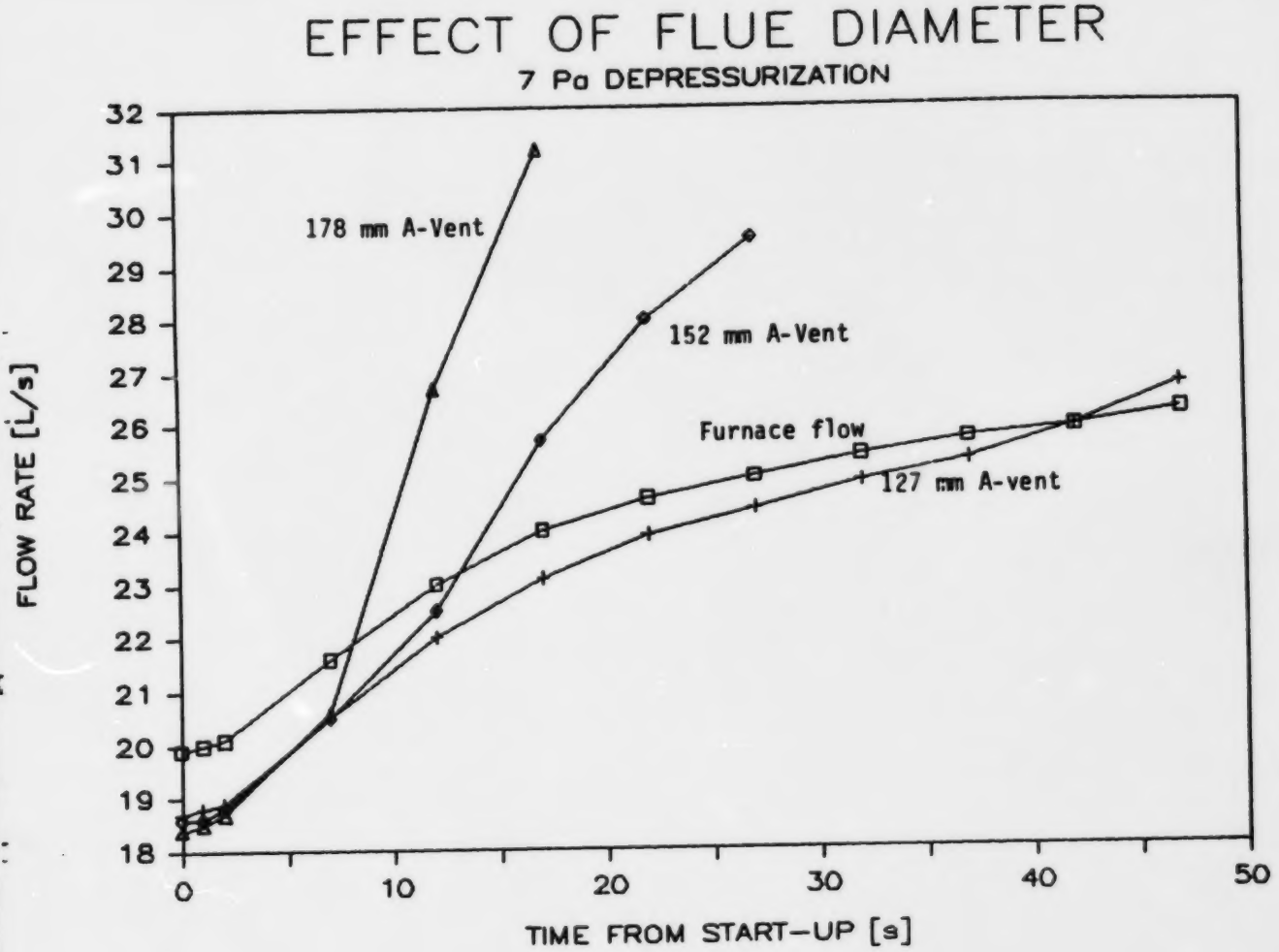

EFFECT OF FLUE DIAMETER
7 Pa DEPRESSURIZATION
178 mm A-Vent
152 mm A-Vent
Furnace flow
127 mm A-vent
FLOW RATE [L/s]
TIME FROM START-UP [s]
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
0
10
20
30
40
50

Figure 3.

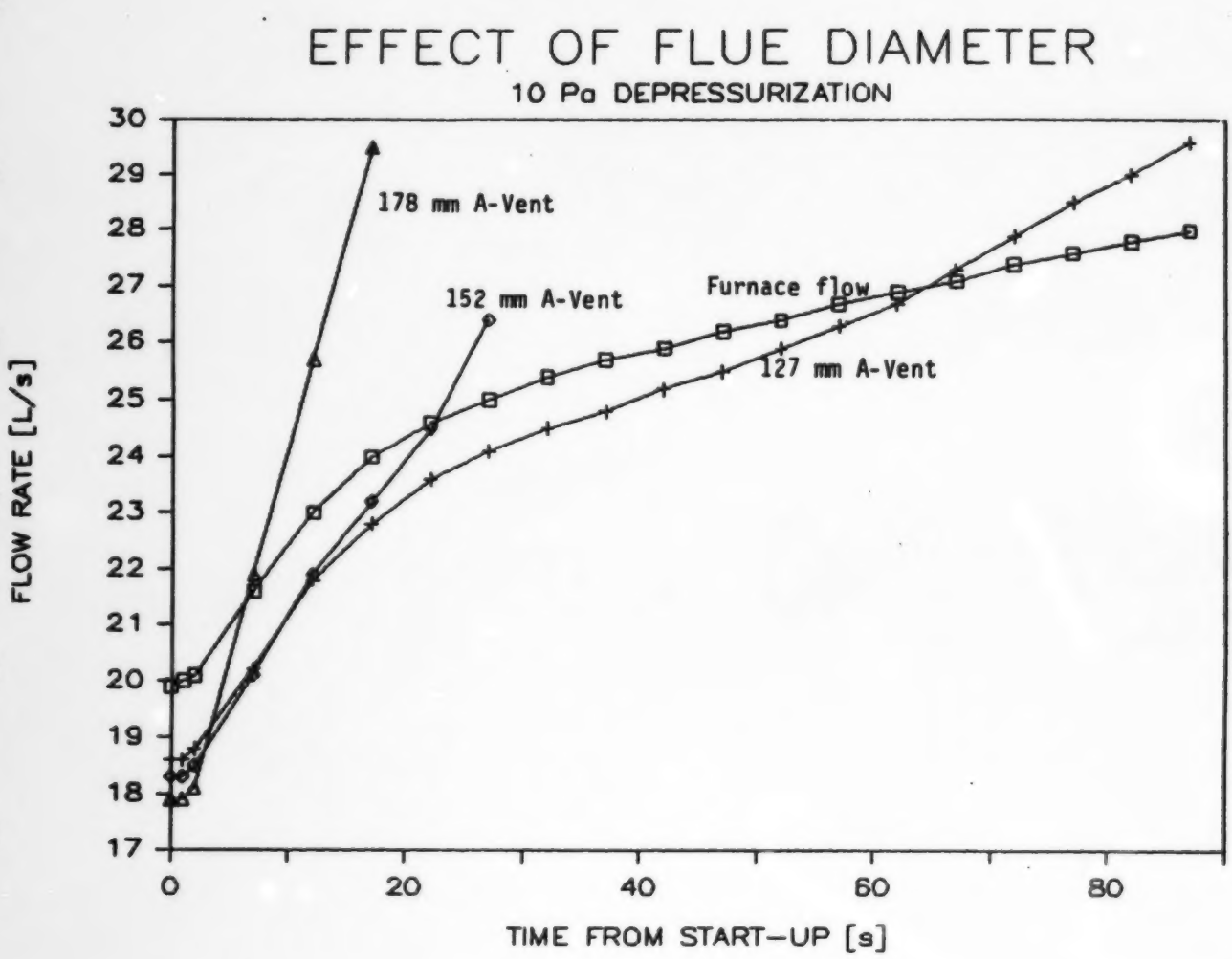

EFFECT OF FLUE DIAMETER
10 Pa DEPRESSURIZATION
178 mm A-Vent
152 mm A-Vent
Furnace flow
127 mm A-Vent
FLOW RATE [L/s]
TIME FROM START-UP [s]
30
29
28
27
26
25
24
23
22
21
20
19
18
17
0
20
40
60
80

Figure 4.

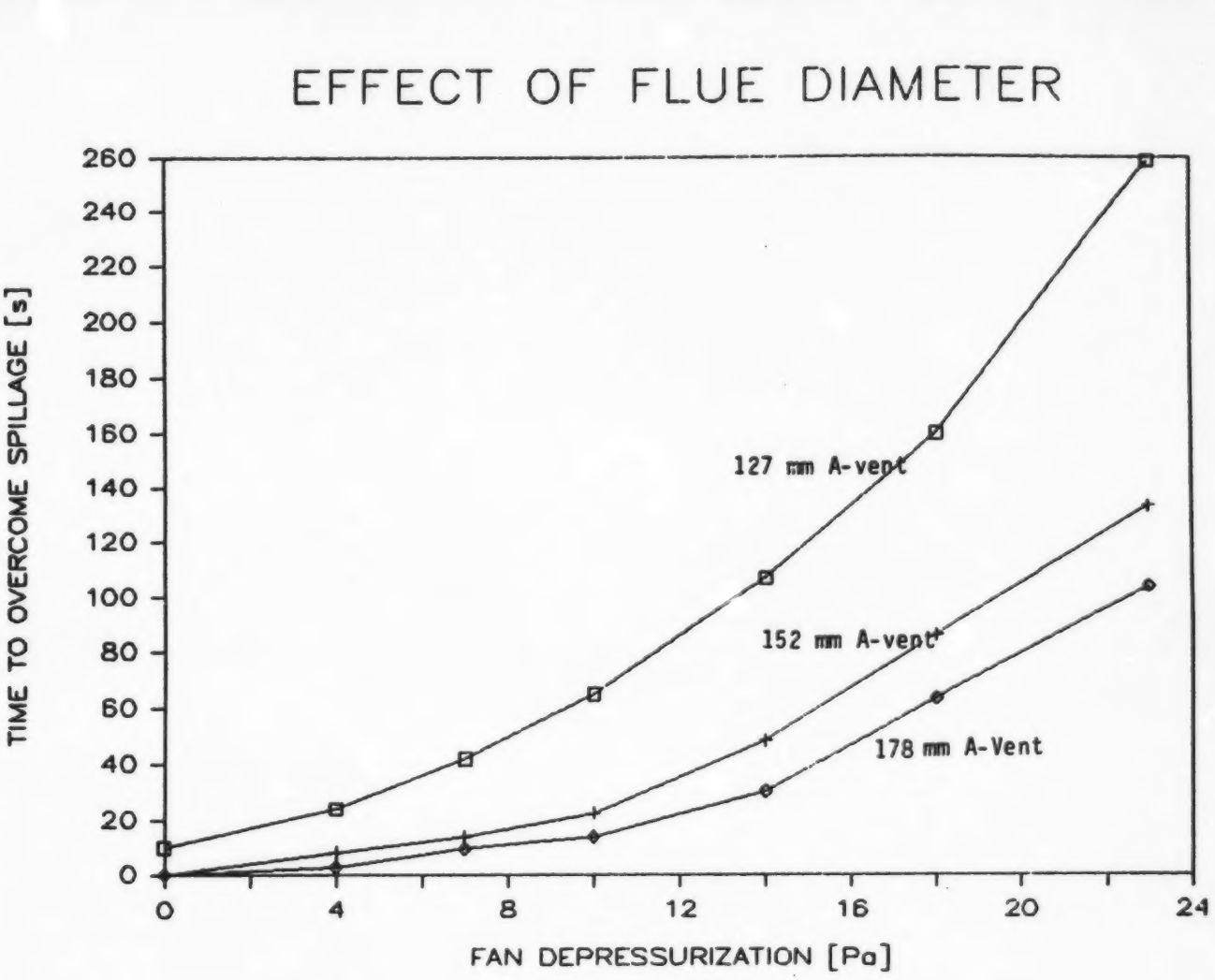

EFFECT OF FLUE DIAMETER
TIME TO OVERCOME SPILLAGE [s]
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
4
8
12
16
20
24
FAN DEPRESSURIZATION [Pa]
127 mm A-vent
152 mm A-vent
178 mm A-Vent

Figure 5.

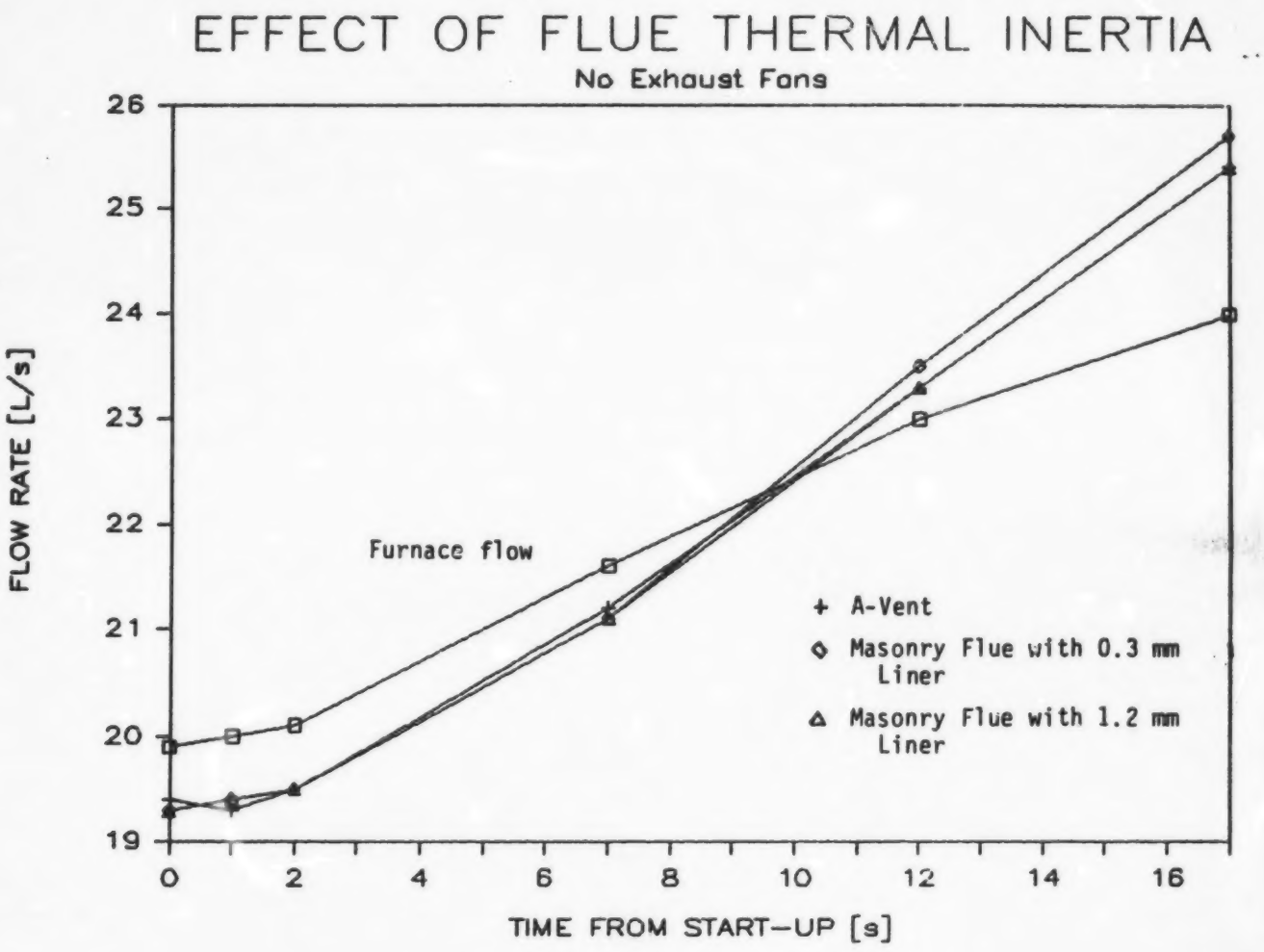

EFFECT OF FLUE THERMAL INERTIA
No Exhaust Fans
FLOW RATE [L/s]
26
25
24
23
22
21
20
19
0
2
4
6
8
10
12
14
16
TIME FROM START-UP [s]
Furnace flow
+ A-Vent
◇ Masonry Flue with 0.3 mm Liner
△ Masonry Flue with 1.2 mm Liner

Figure 6.

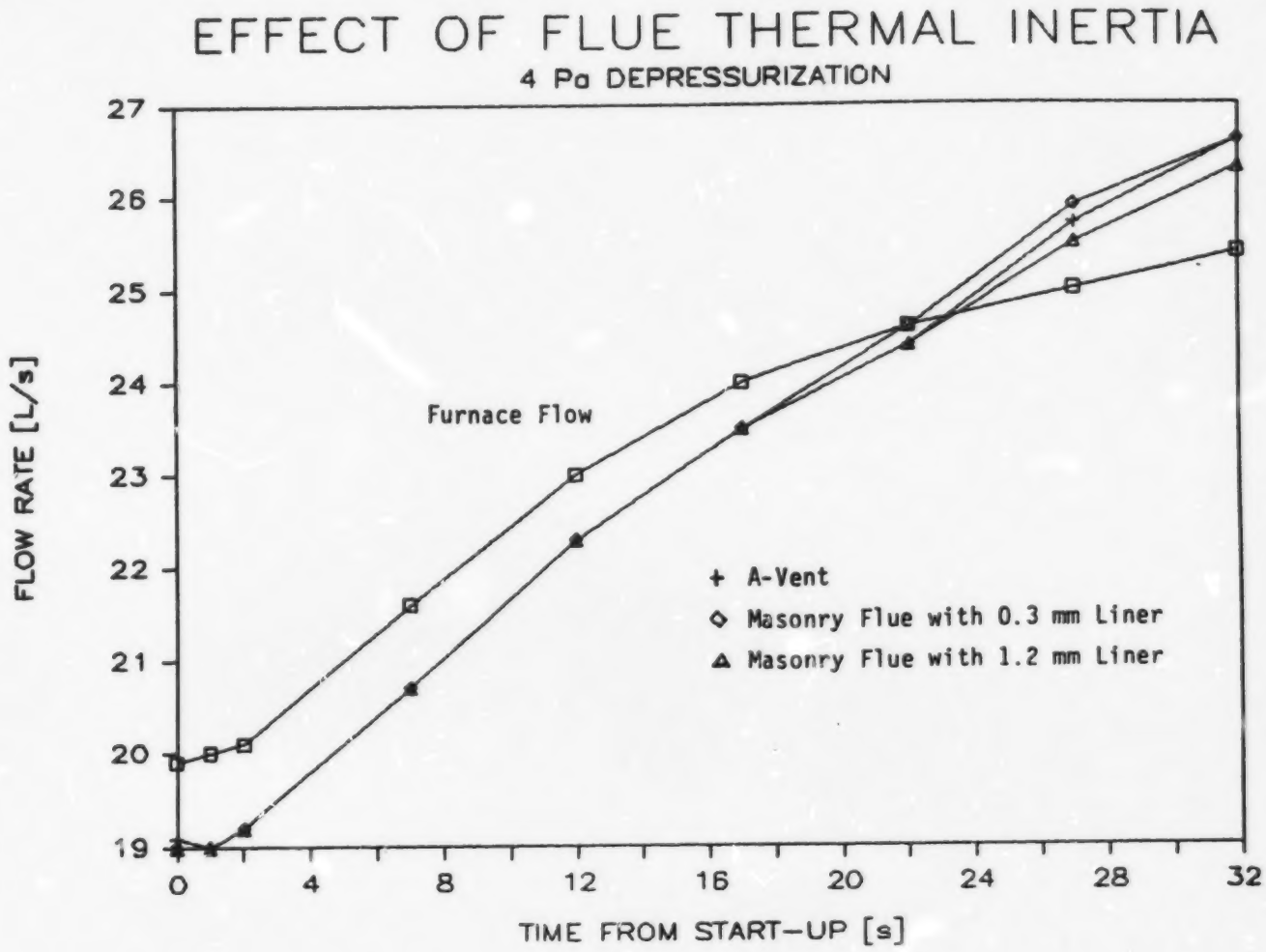

EFFECT OF FLUE THERMAL INERTIA
4 Pa DEPRESSURIZATION
FLOW RATE [L/s]
TIME FROM START-UP [s]
Furnace Flow
+ A-Vent
◇ Masonry Flue with 0.3 mm Liner
△ Masonry Flue with 1.2 mm Liner
27
26
25
24
23
22
21
20
19
0
4
8
12
16
20
24
28
32

Figure 7.

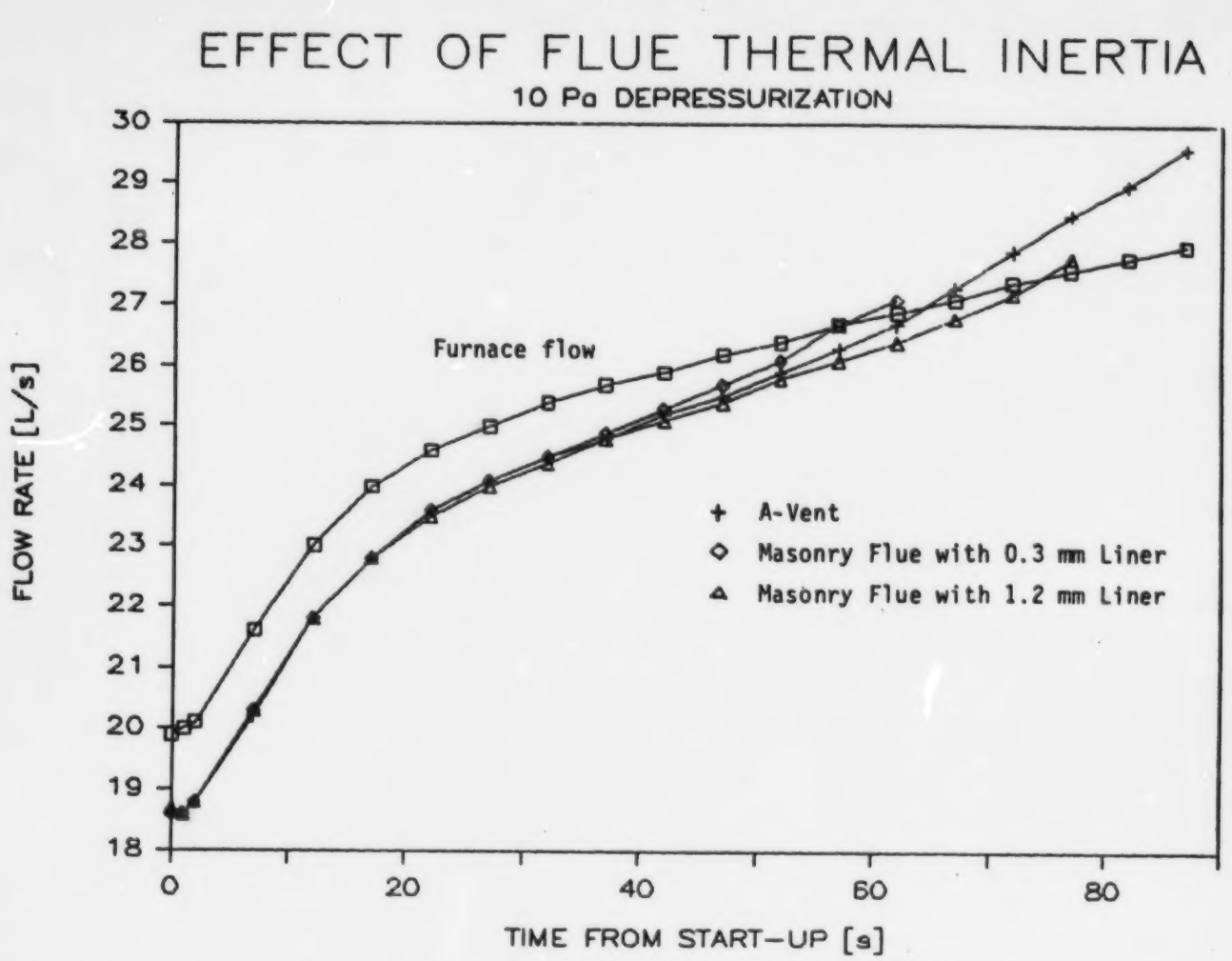

EFFECT OF FLUE THERMAL INERTIA
10 Pa DEPRESSURIZATION
FLOW RATE [L/s]
30
29
28
27
26
25
24
23
22
21
20
19
18
Furnace flow
+ A-Vent
◇ Masonry Flue with 0.3 mm Liner
△ Masonry Flue with 1.2 mm Liner
0
20
40
60
80
TIME FROM START-UP [s]

Figure 8.

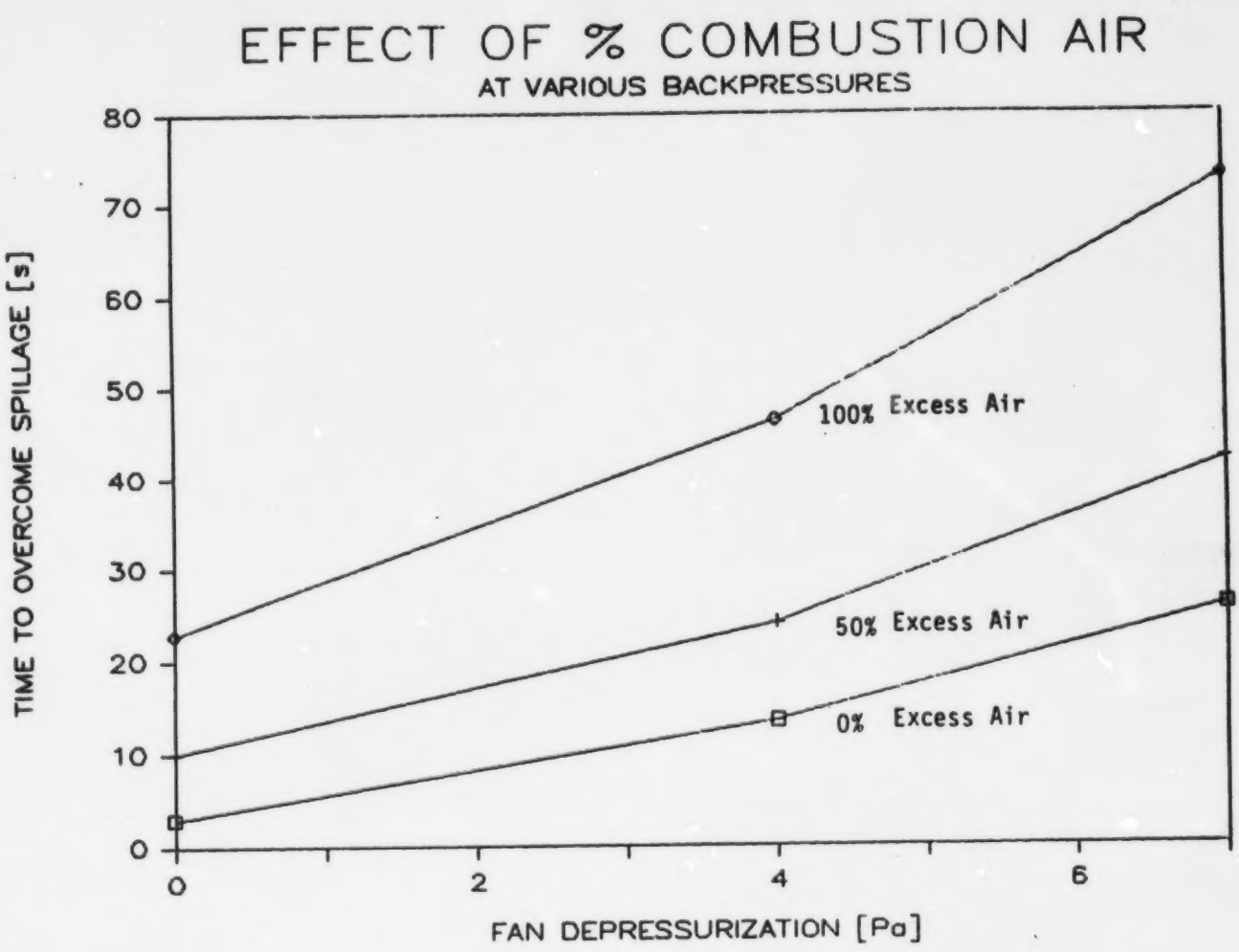

EFFECT OF % COMBUSTION AIR
AT VARIOUS BACKPRESSURES
TIME TO OVERCOME SPILLAGE [s]
80
70
60
50
40
30
20
10
0
0
2
4
6
FAN DEPRESSURIZATION [Pa]
100% Excess Air
50% Excess Air
0% Excess Air

Figure 9.

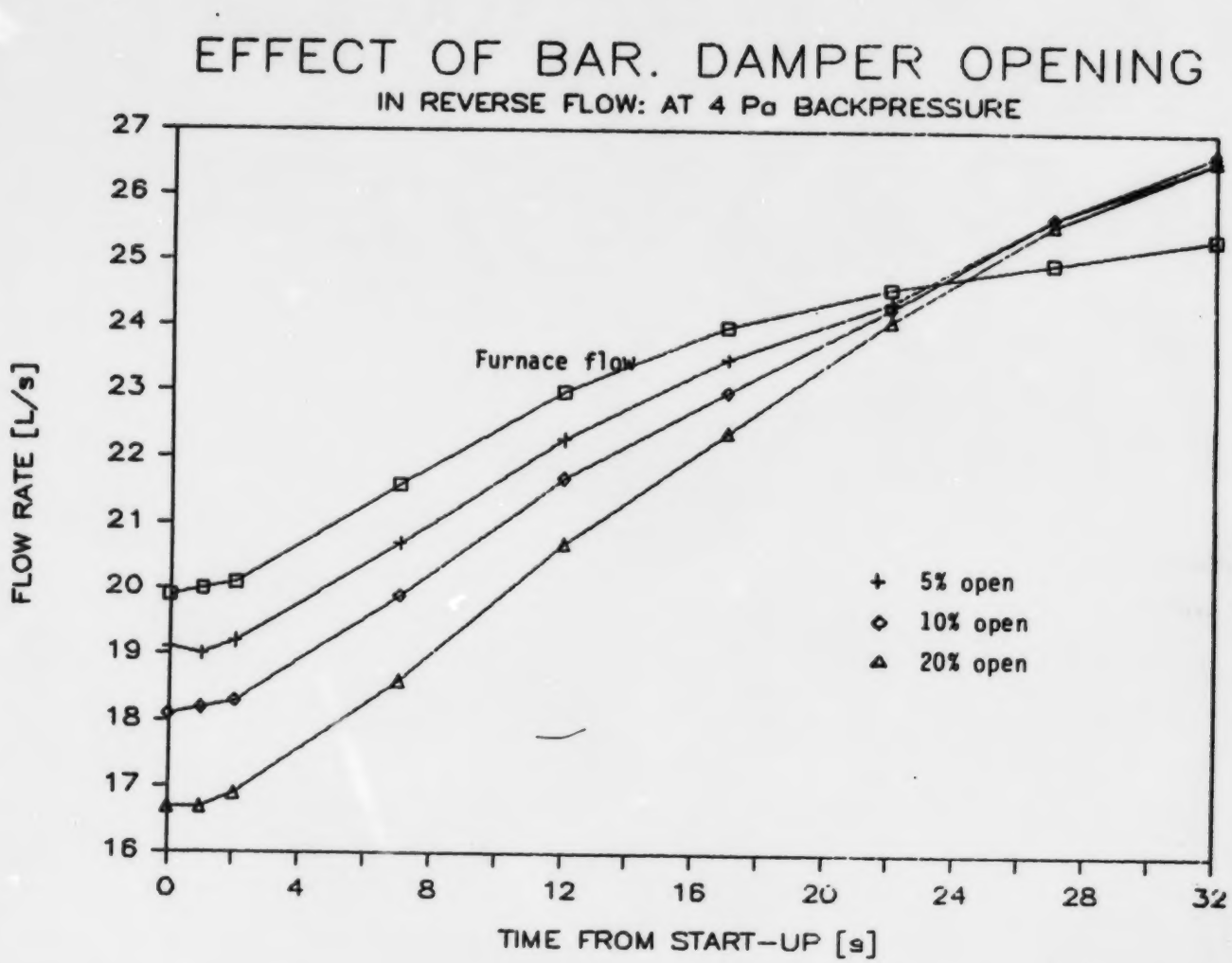

EFFECT OF BAR. DAMPER OPENING
IN REVERSE FLOW: AT 4 Pa BACKPRESSURE
FLOW RATE [L/s]
TIME FROM START-UP [s]
Furnace flow
5% open
10% open
20% open
27
26
25
24
23
22
21
20
19
18
17
16
0
4
8
12
16
20
24
28
32

Figure 10.

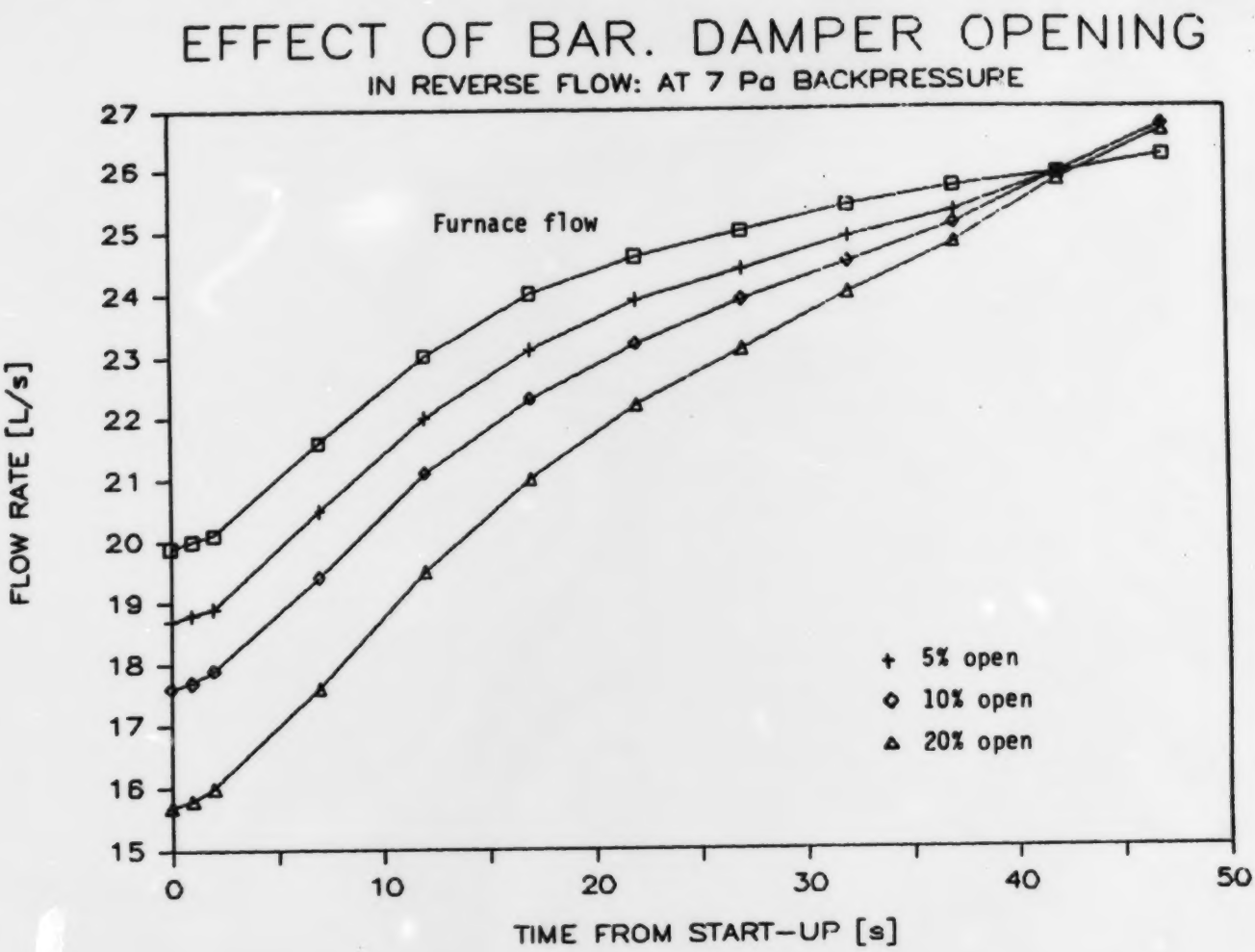

EFFECT OF BAR. DAMPER OPENING
IN REVERSE FLOW: AT 7 Pa BACKPRESSURE
Furnace flow
5% open
10% open
20% open
FLOW RATE [L/s]
TIME FROM START-UP [s]
27
26
25
24
23
22
21
20
19
18
17
16
15
0
10
20
30
40
50

Figure 11.

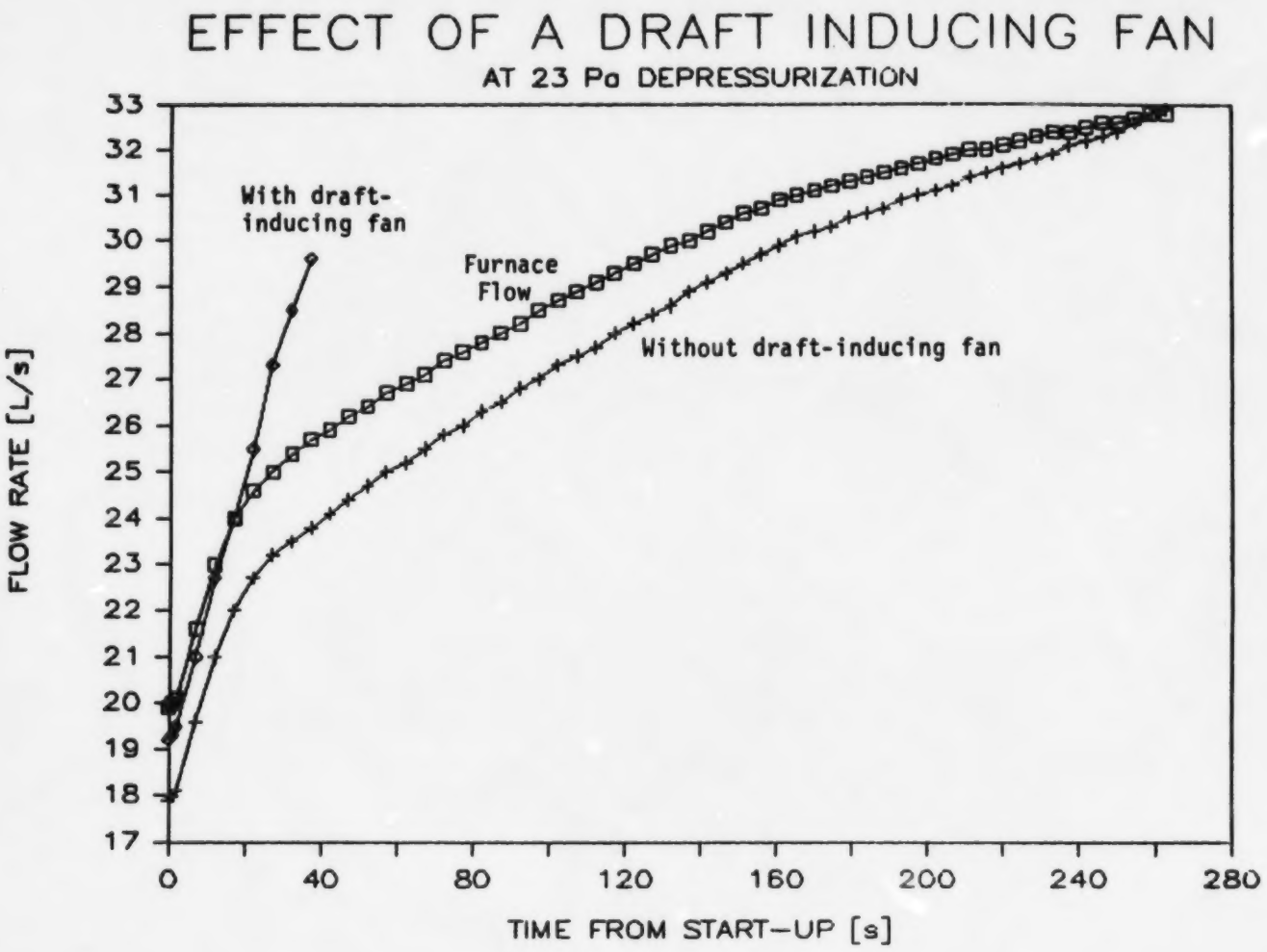

EFFECT OF A DRAFT INDUCING FAN
AT 23 Pa DEPRESSURIZATION
With draft-inducing fan
Furnace Flow
Without draft-inducing fan
FLOW RATE [L/s]
TIME FROM START-UP [s]
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
0
40
80
120
160
200
240
280

Figure 12.

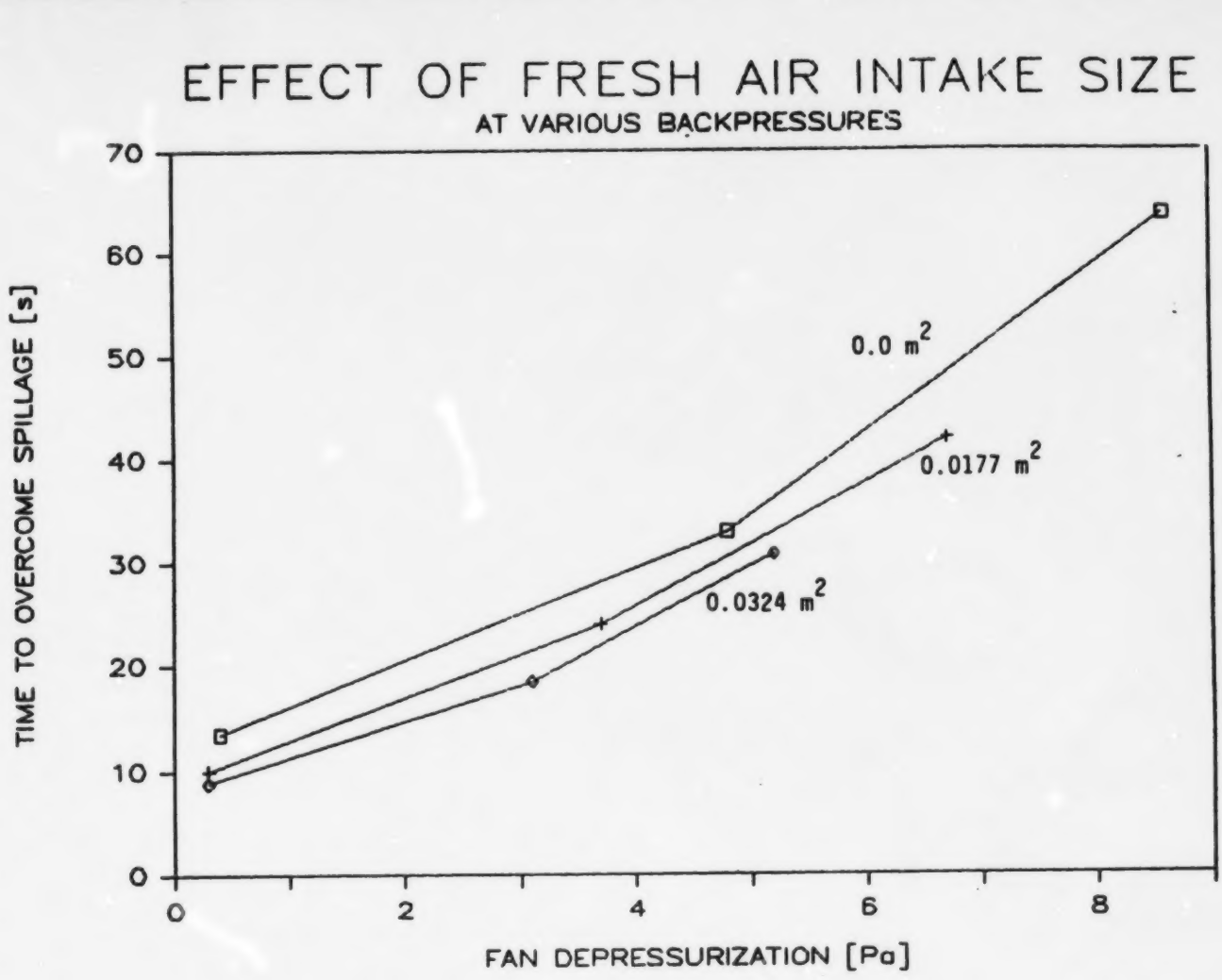

EFFECT OF FRESH AIR INTAKE SIZE
AT VARIOUS BACKPRESSURES
TIME TO OVERCOME SPILLAGE [s]
FAN DEPRESSURIZATION [Pa]
0.0 m2
0.0177 m2
0.0324 m2
0
10
20
30
40
50
60
70
0
2
4
6
8

Figure 13.

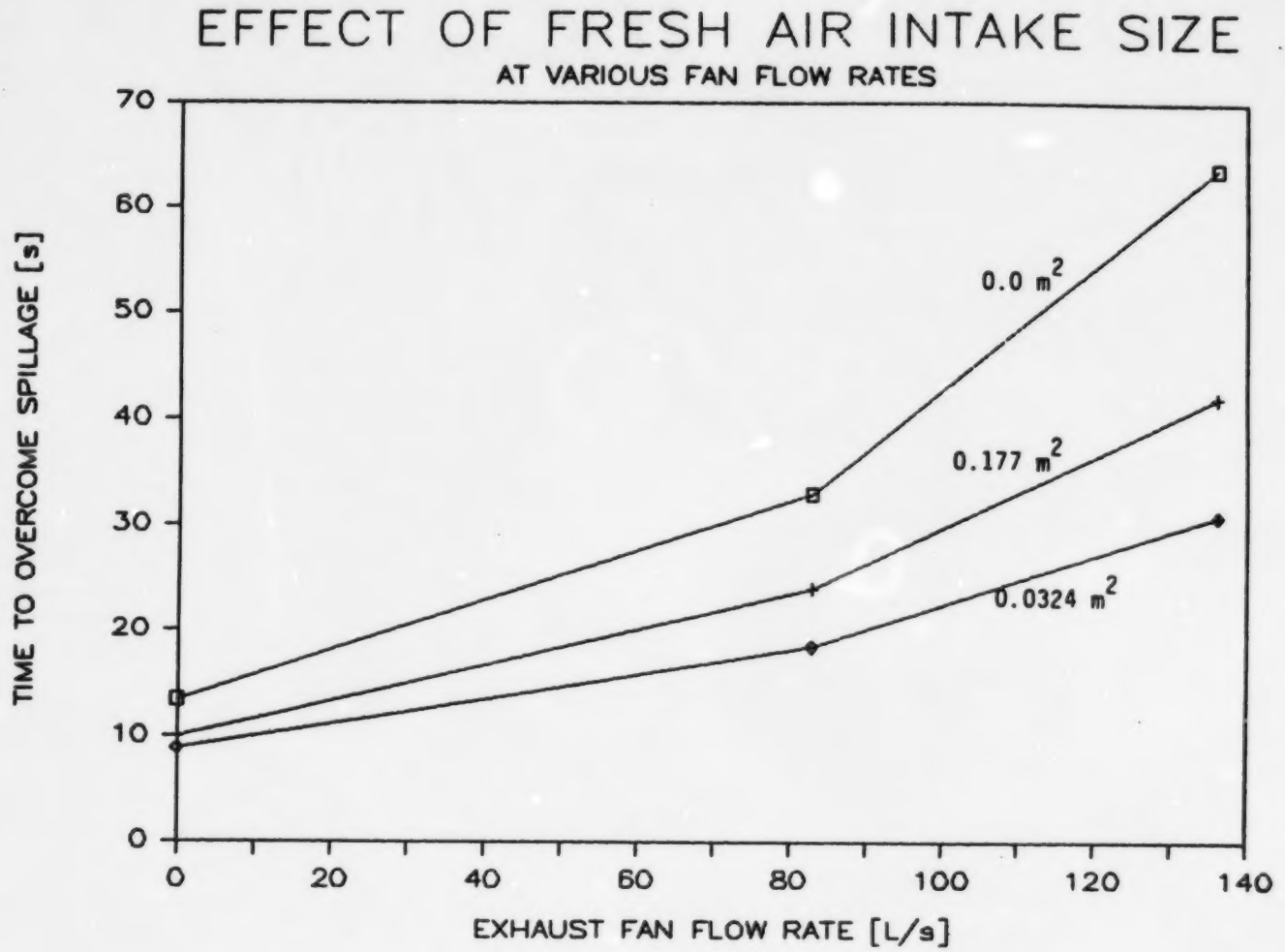

EFFECT OF FRESH AIR INTAKE SIZE
AT VARIOUS FAN FLOW RATES
TIME TO OVERCOME SPILLAGE [s]
EXHAUST FAN FLOW RATE [L/s]
0.0 m2
0.177 m2
0.0324 m2
0
10
20
30
40
50
60
70
0
20
40
60
80
100
120
140

Figure 14.

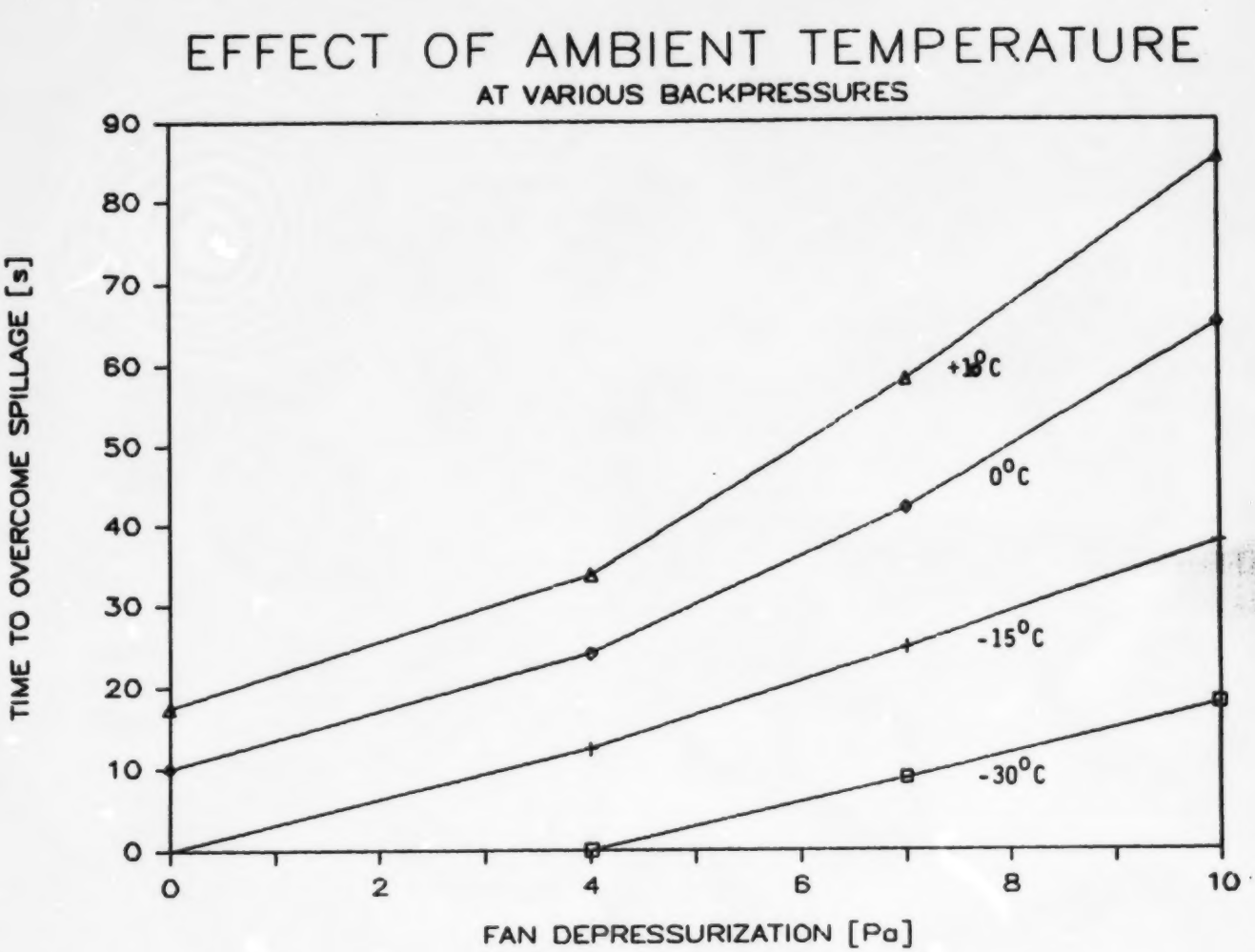

EFFECT OF AMBIENT TEMPERATURE
AT VARIOUS BACKPRESSURES
TIME TO OVERCOME SPILLAGE [s]
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
FAN DEPRESSURIZATION [Pa]
+15°C
0°C
-15°C
-30°C

Figure 15.

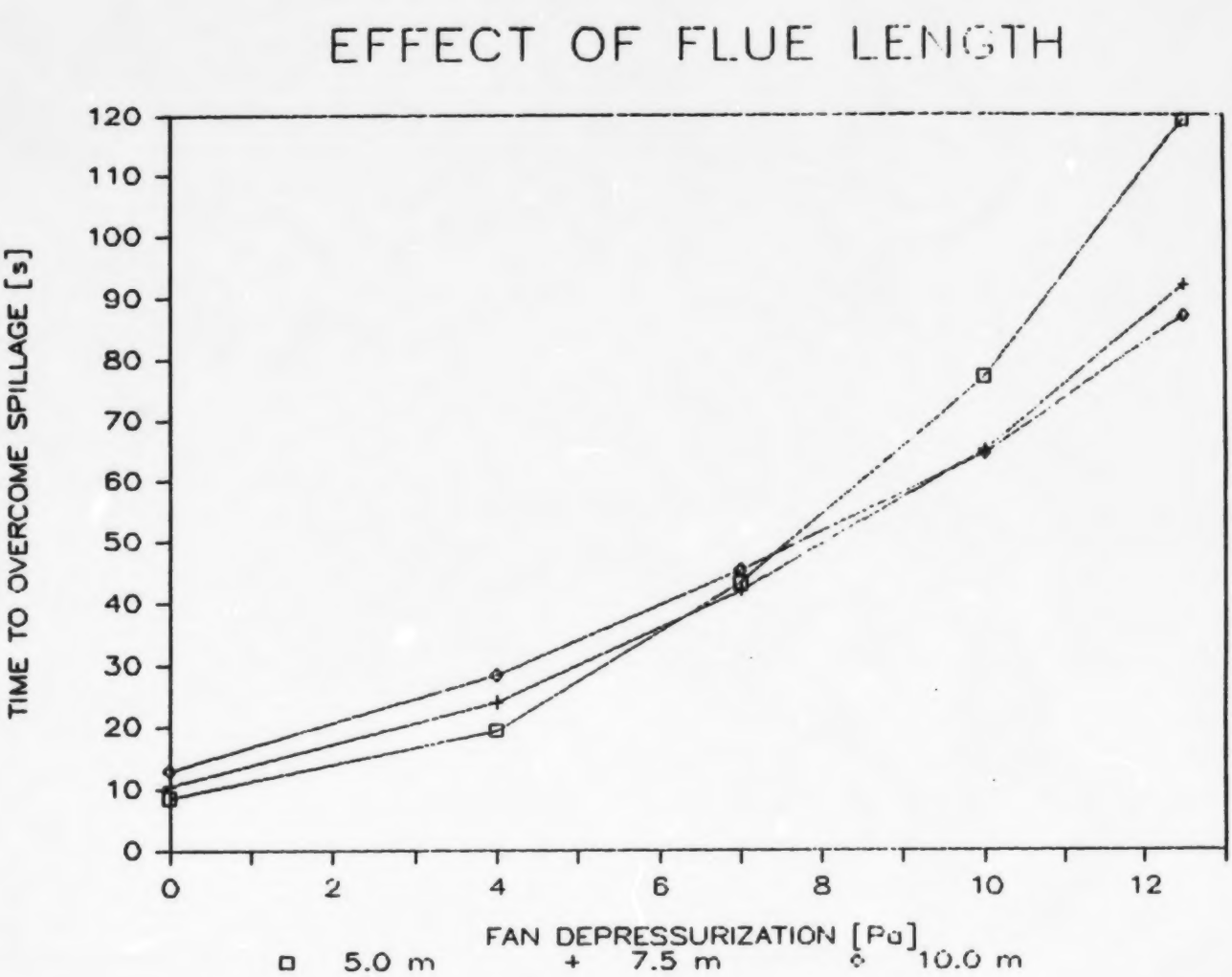

EFFECT OF FLUE LENGTH
TIME TO OVERCOME SPILLAGE [s]
120
110
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
FAN DEPRESSURIZATION [Pa]
□ 5.0 m
+ 7.5 m
◇ 10.0 m

Figure 16.

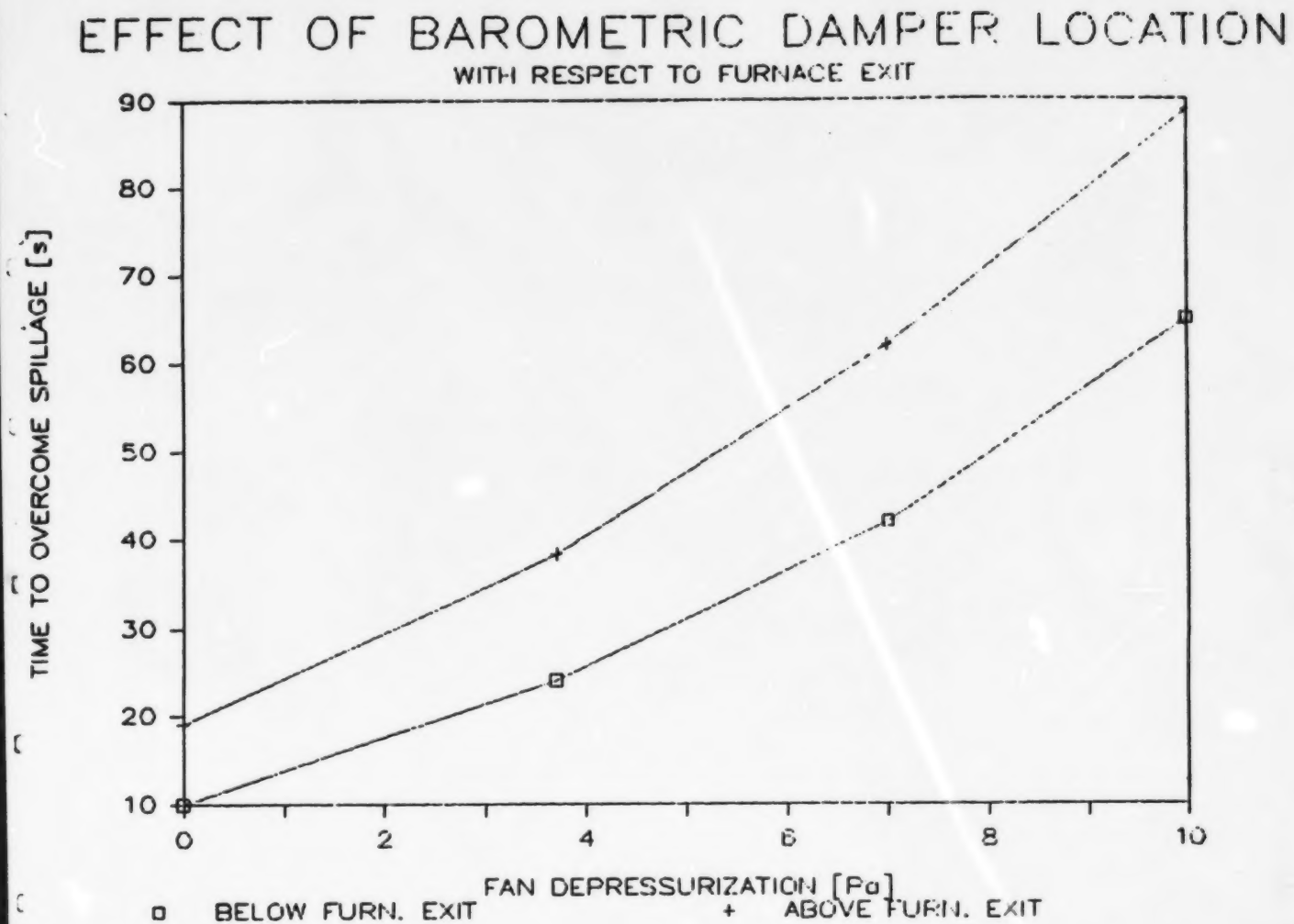

EFFECT OF BAROMETRIC DAMPER LOCATION
WITH RESPECT TO FURNACE EXIT
TIME TO OVERCOME SPILLAGE [s]
90
80
70
60
50
40
30
20
10
0
2
4
6
8
10
FAN DEPRESSURIZATION [Pa]
BELOW FURN. EXIT
ABOVE FURN. EXIT

Figure 17.

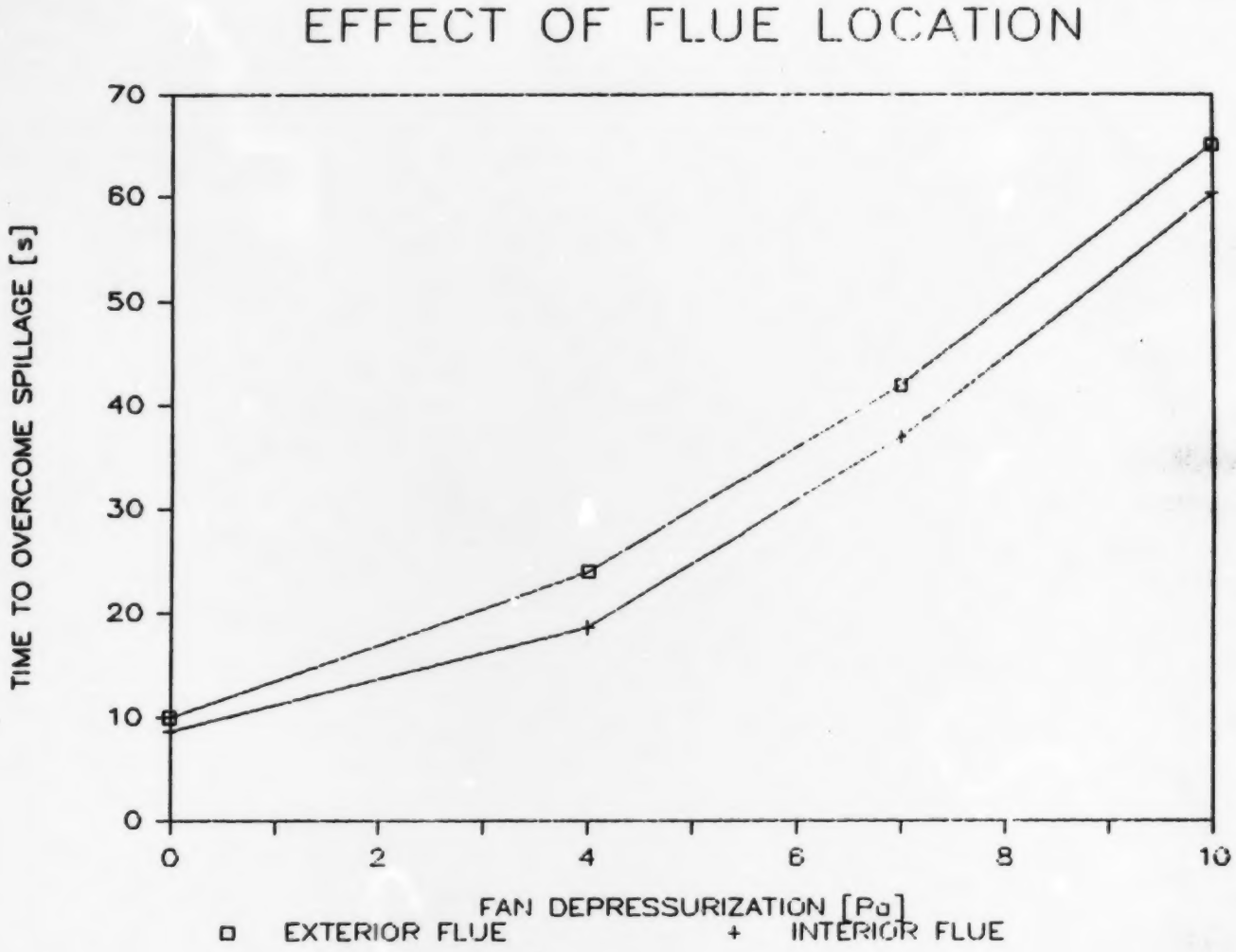

EFFECT OF FLUE LOCATION
TIME TO OVERCOME SPILLAGE [s]
70
60
50
40
30
20
10
0
0
2
4
6
8
10
FAN DEPRESSURIZATION [Pa]
EXTERIOR FLUE
INTERIOR FLUE

Figure 18.

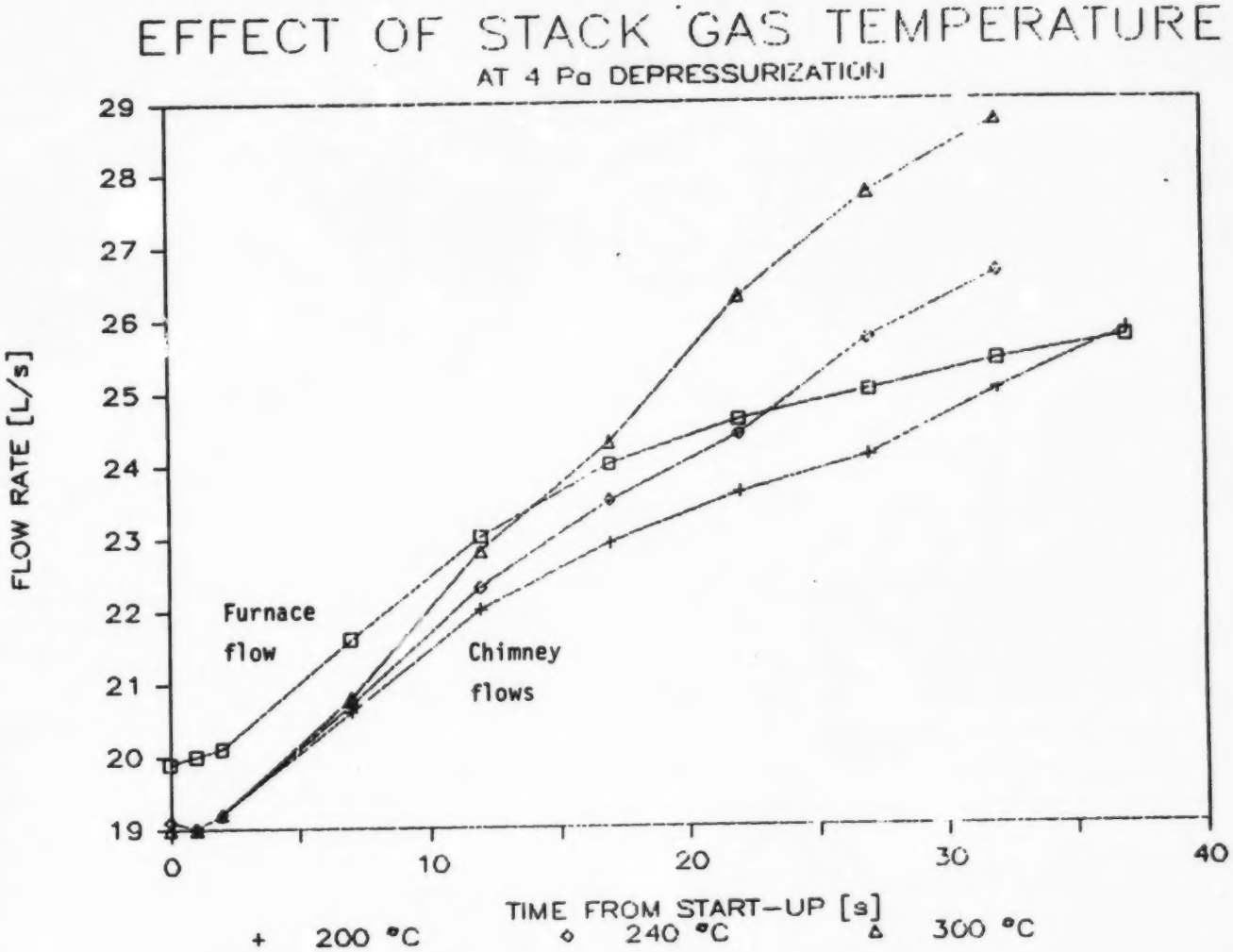

EFFECT OF STACK GAS TEMPERATURE
AT 4 Pa DEPRESSURIZATION
FLOW RATE [L/s]
29
28
27
26
25
24
23
22
21
20
19
0
10
20
30
40
TIME FROM START-UP [s]
Furnace flow
Chimney flows
+ 200 °C
◇ 240 °C
△ 300 °C

Figure 19.

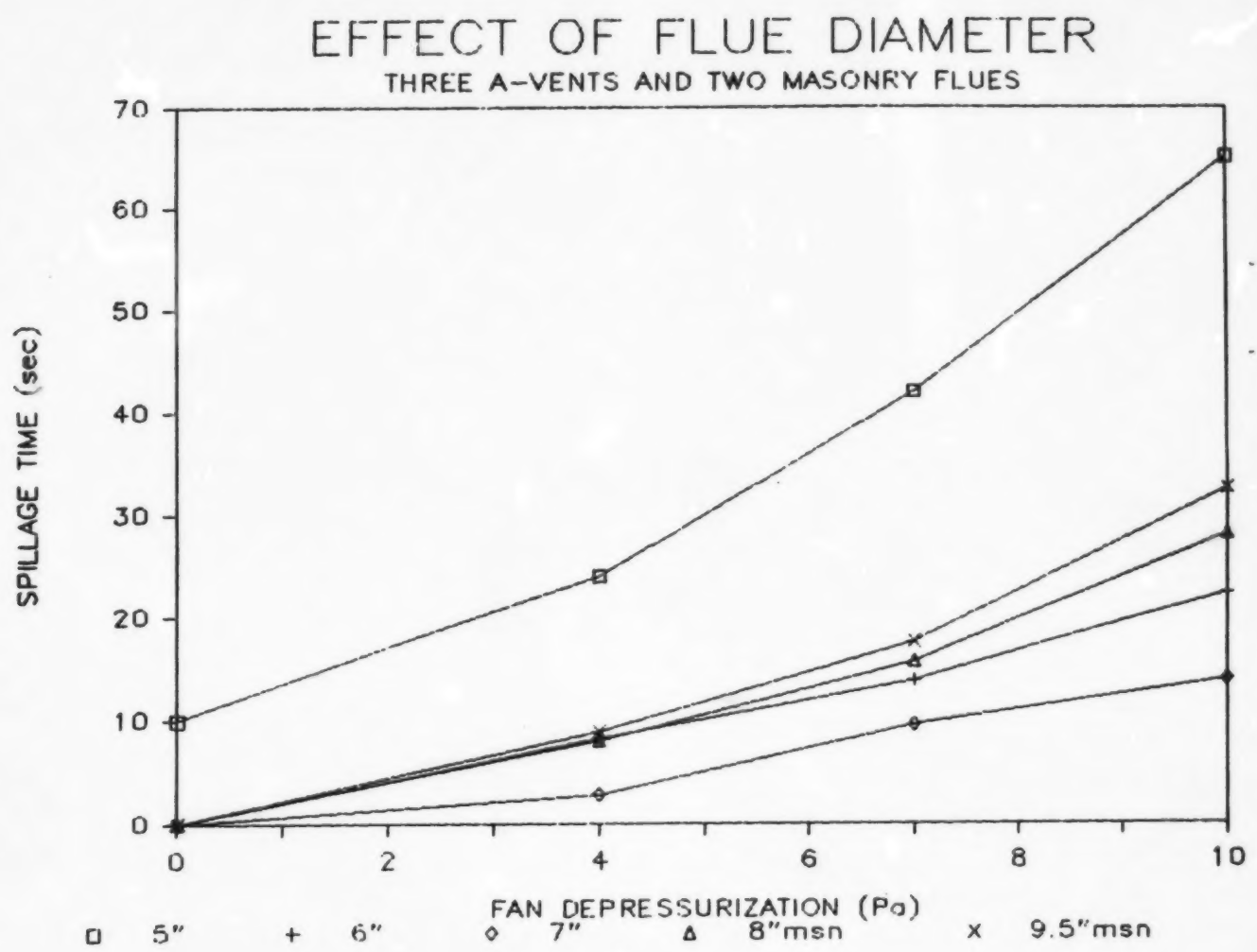

EFFECT OF FLUE DIAMETER
THREE A-VENTS AND TWO MASONRY FLUES
SPILLAGE TIME (sec)
70
60
50
40
30
20
10
0
0
2
4
6
8
10
FAN DEPRESSURIZATION (Pa)
□ 5"
+ 6"
◇ 7"
△ 8"msn
x 9.5"msn

Figure 20.

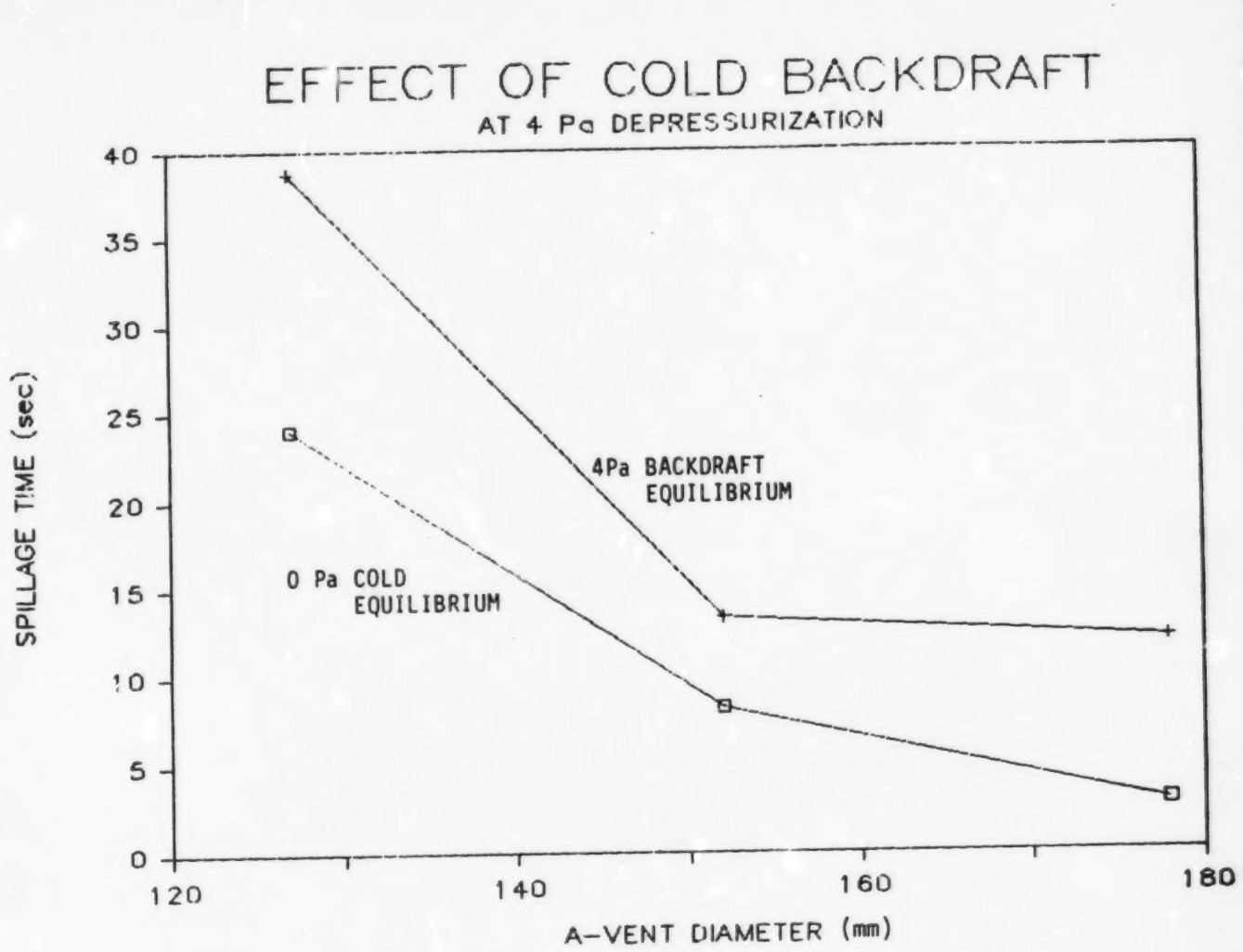
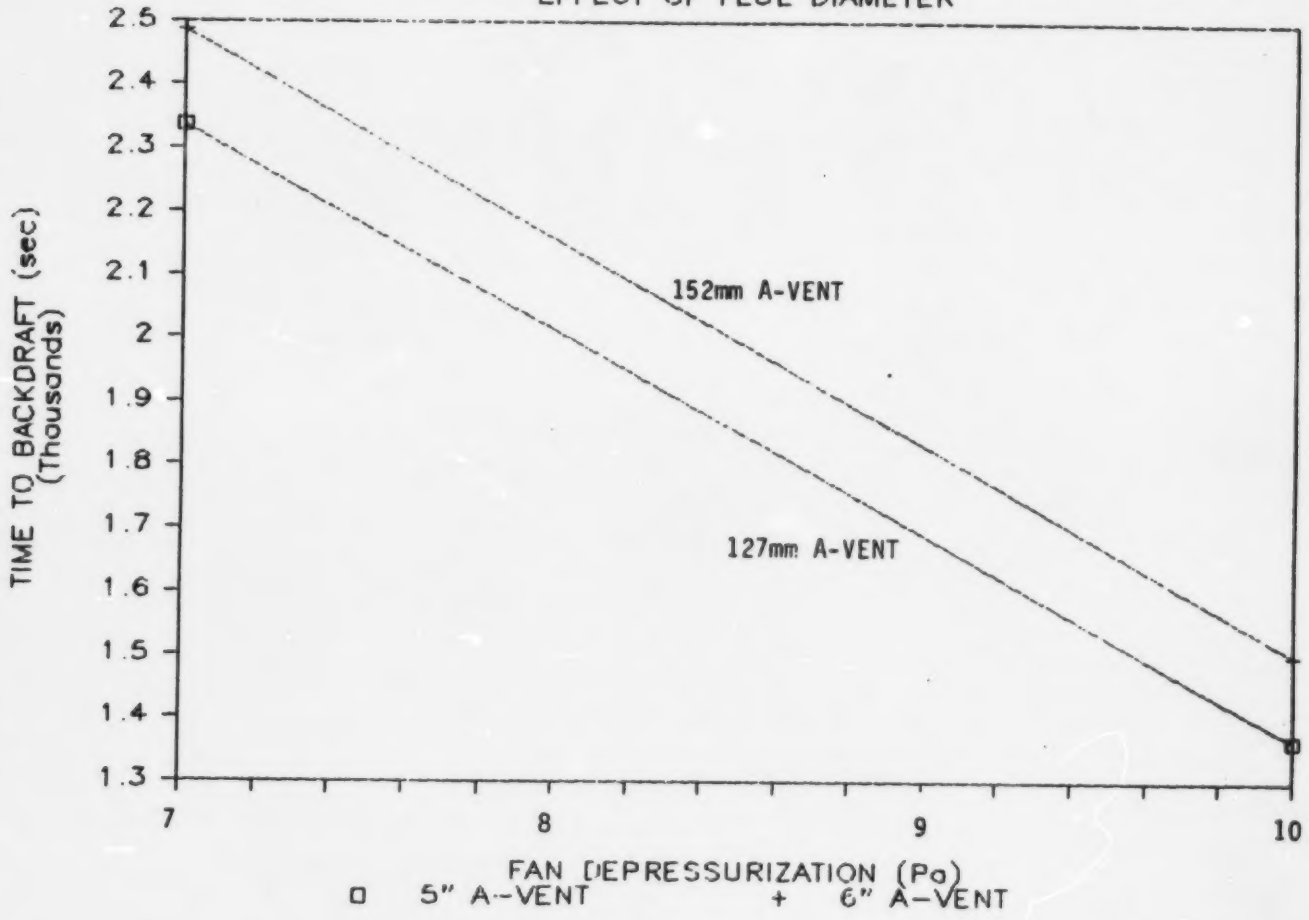

EFFECT OF COLD BACKDRAFT
AT 4 Pa DEPRESSURIZATION
SPILLAGE TIME (sec)
40
35
30
25
20
15
10
5
0
120
140
160
180
A-VENT DIAMETER (mm)
4Pa BACKDRAFT EQUILIBRIUM
0 Pa COLD EQUILIBRIUM

Figure 21.

TIME TO BACKDRAFT

EFFECT OF FLUE DIAMETER



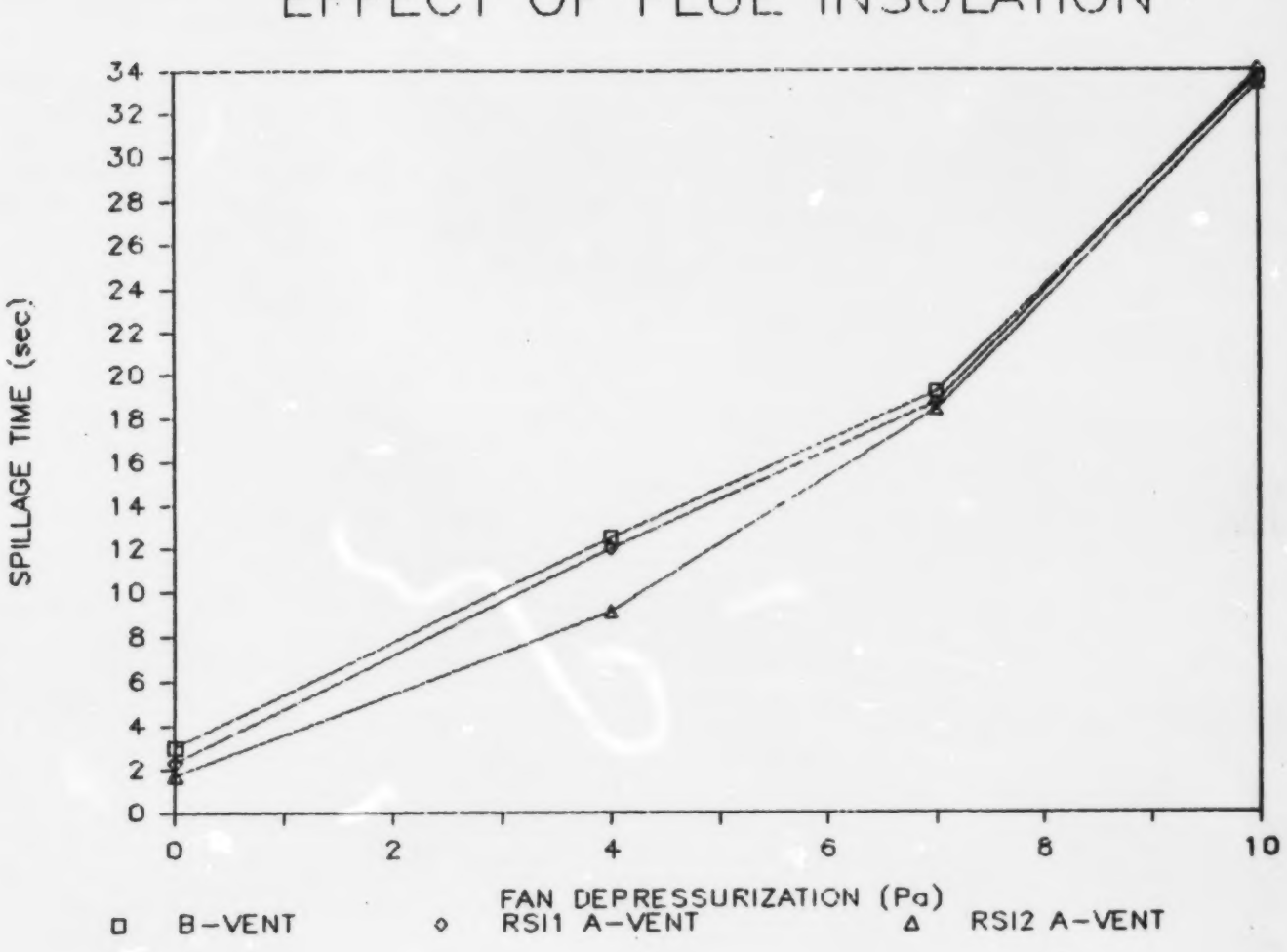

EFFECT OF FLUE INSULATION
SPILLAGE TIME (sec)
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0
2
4
6
8
10
FAN DEPRESSURIZATION (Pa)
□ B-VENT
◇ RSI1 A-VENT
△ RSI2 A-VENT

Figure 23.

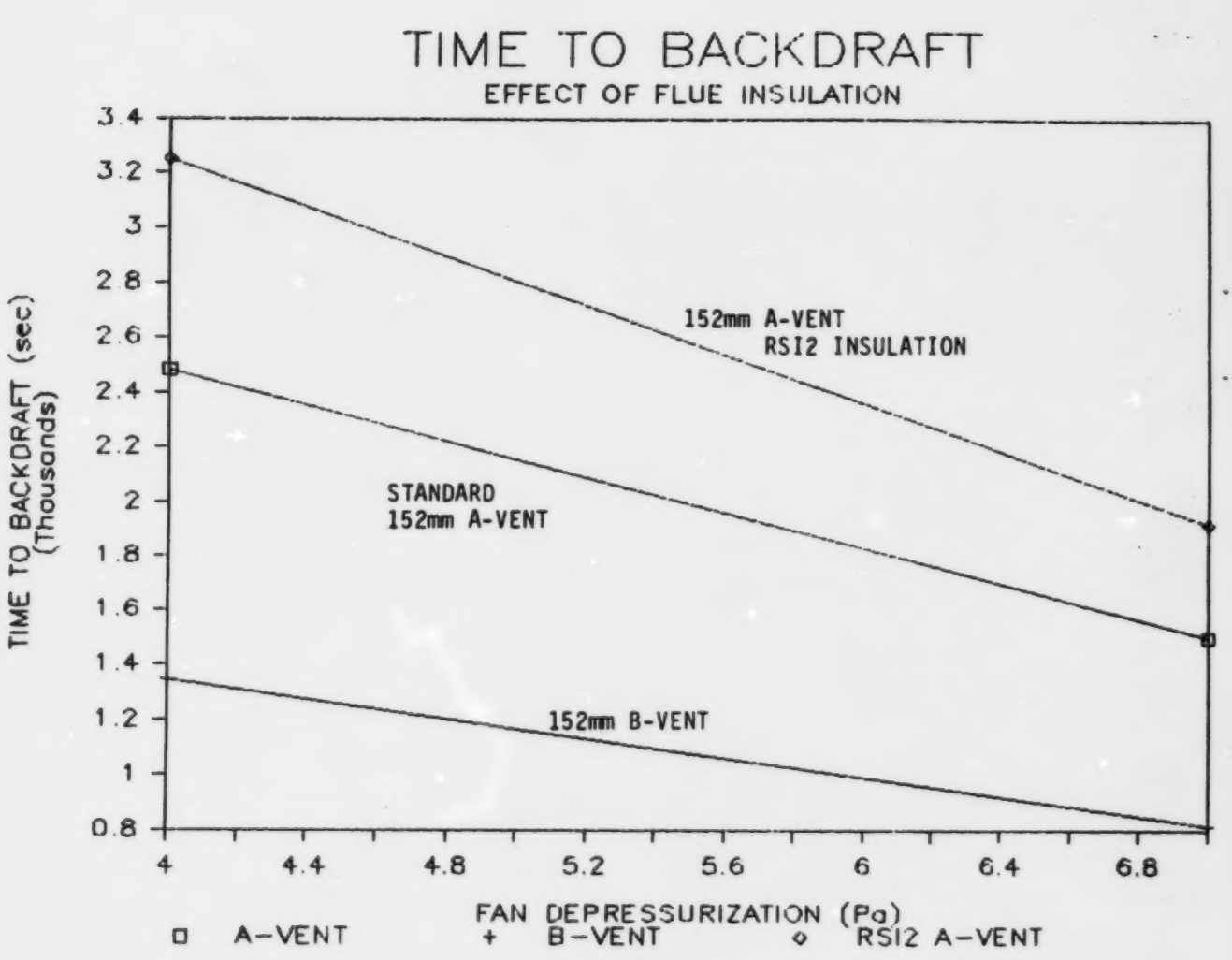

TIME TO BACKDRAFT
EFFECT OF FLUE INSULATION
TIME TO BACKDRAFT (sec)
(Thousands)
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
152mm A-VENT
RSI2 INSULATION
STANDARD
152mm A-VENT
152mm B-VENT
4
4.4
4.8
5.2
5.6
6
6.4
6.8
FAN DEPRESSURIZATION (Pa)
□ A-VENT
+ B-VENT
◇ RSI2 A-VENT

Figure 24.

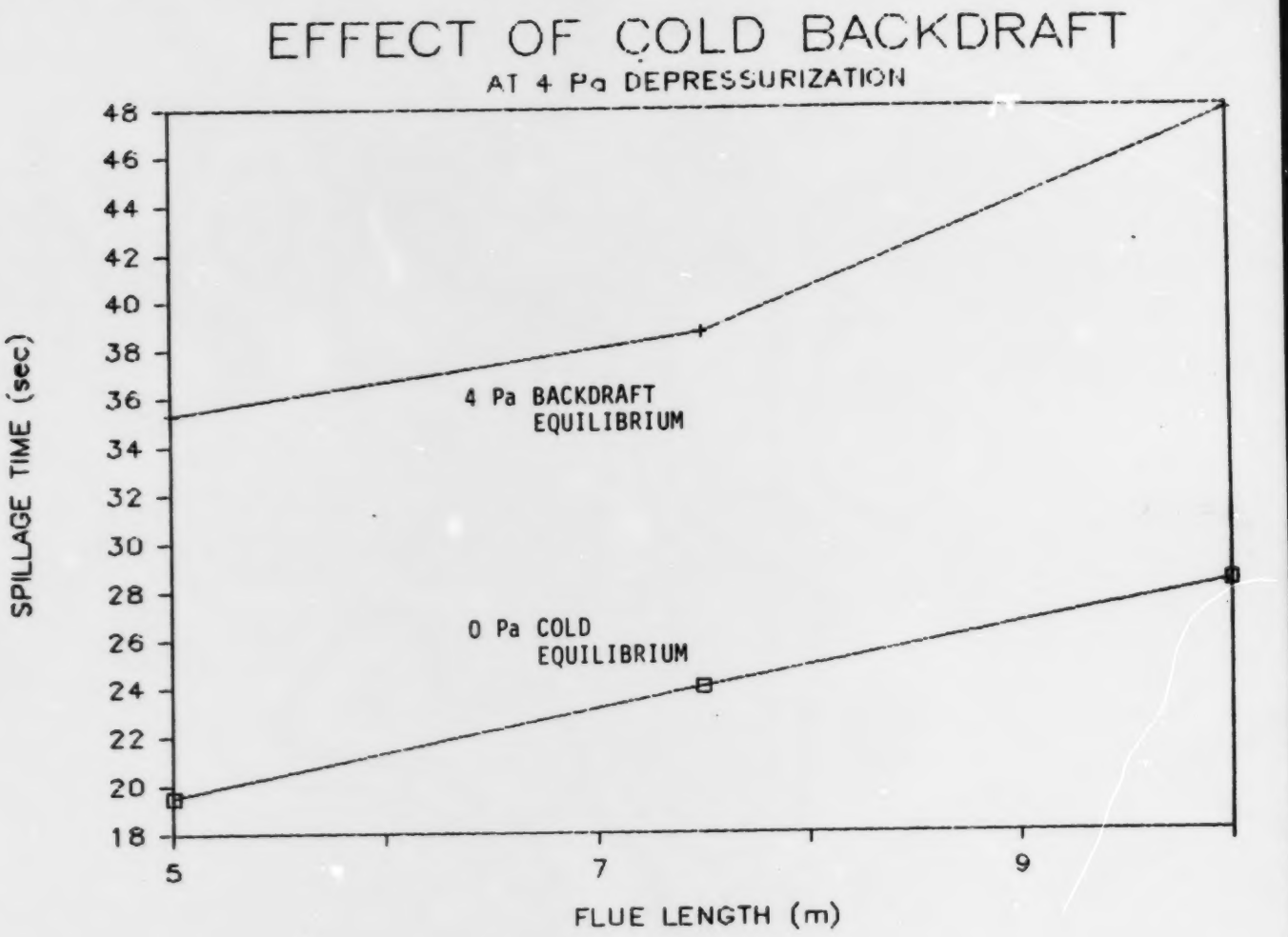

EFFECT OF COLD BACKDRAFT
AT 4 Pa DEPRESSURIZATION
SPILLAGE TIME (sec)
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
4 Pa BACKDRAFT
EQUILIBRIUM
0 Pa COLD
EQUILIBRIUM
5
7
9
FLUE LENGTH (m)

Figure 25.

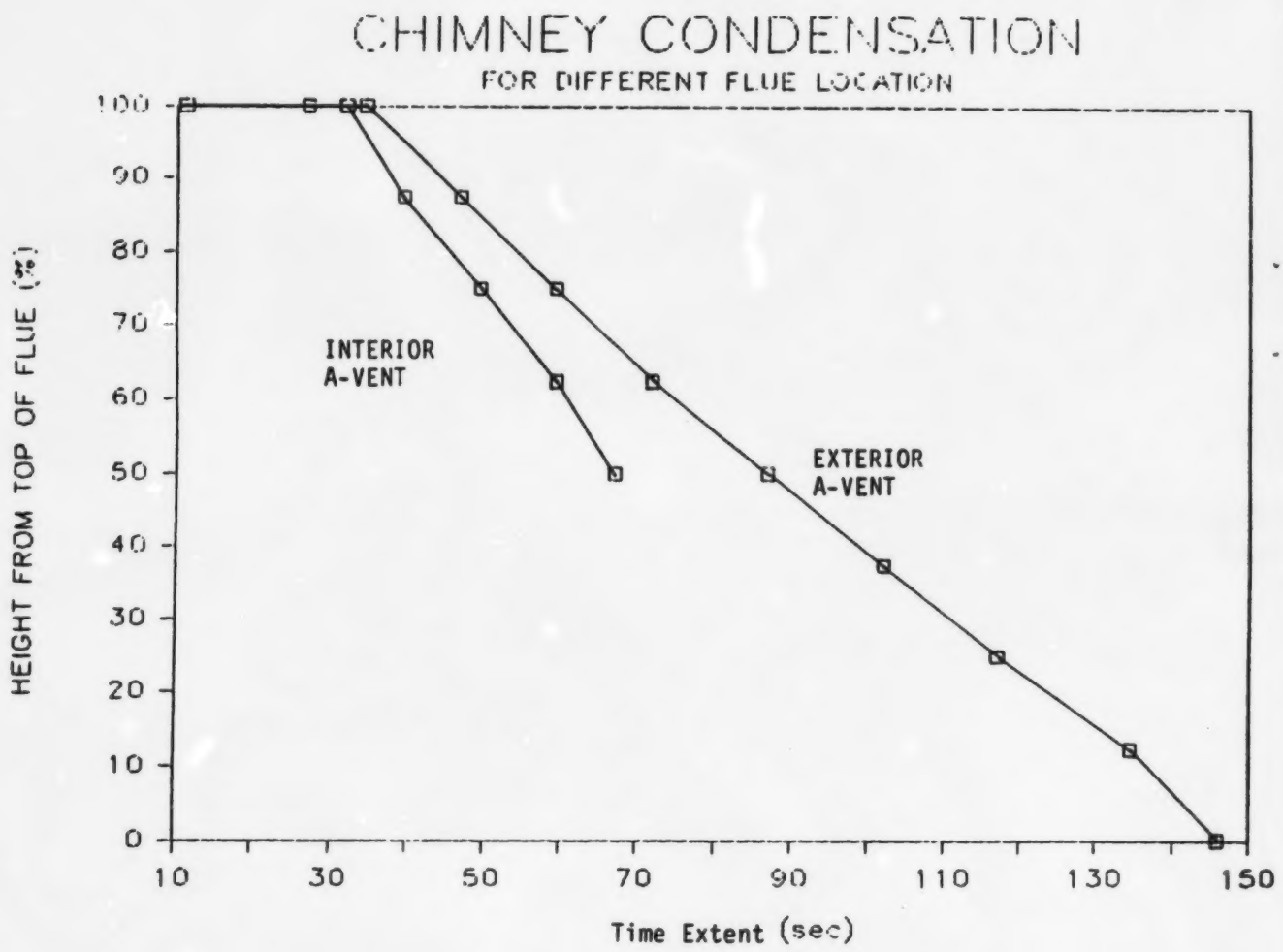

CHIMNEY CONDENSATION
FOR DIFFERENT FLUE LOCATION
HEIGHT FROM TOP OF FLUE (%)
100
90
80
70
60
50
40
30
20
10
0
INTERIOR
A-VENT
EXTERIOR
A-VENT
10
30
50
70
90
110
130
150
Time Extent (sec)

Figure 26.

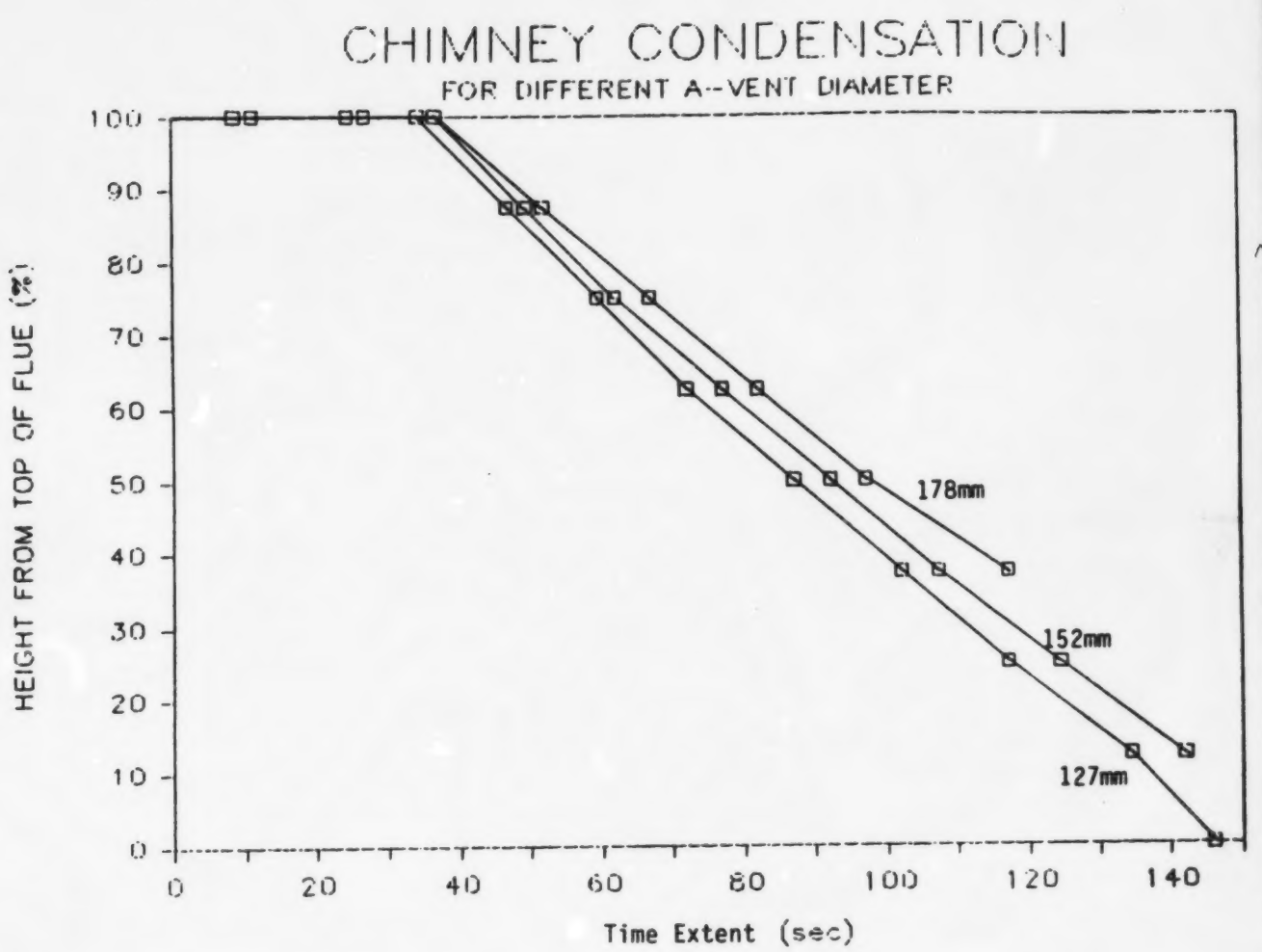

CHIMNEY CONDENSATION
FOR DIFFERENT A--VENT DIAMETER
HEIGHT FROM TOP OF FLUE (%)
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
Time Extent (sec)
178mm
152mm
127mm

Figure 27.

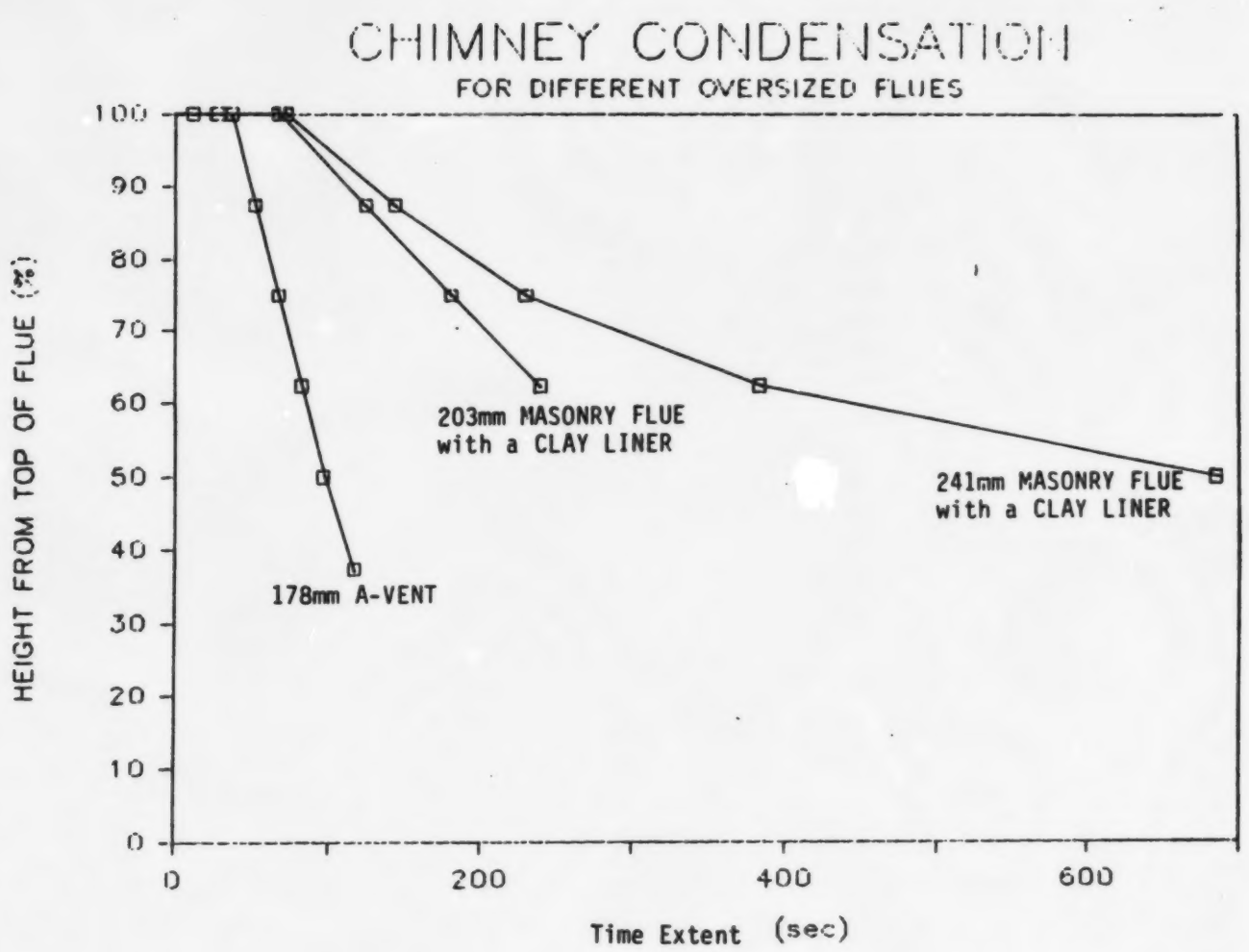

CHIMNEY CONDENSATION
FOR DIFFERENT OVERSIZED FLUES
HEIGHT FROM TOP OF FLUE (%)
100
90
80
70
60
50
40
30
20
10
0
0
200
400
600
Time Extent (sec)
203mm MASONRY FLUE
with a CLAY LINER
241mm MASONRY FLUE
with a CLAY LINER
178mm A-VENT

Figure 28.

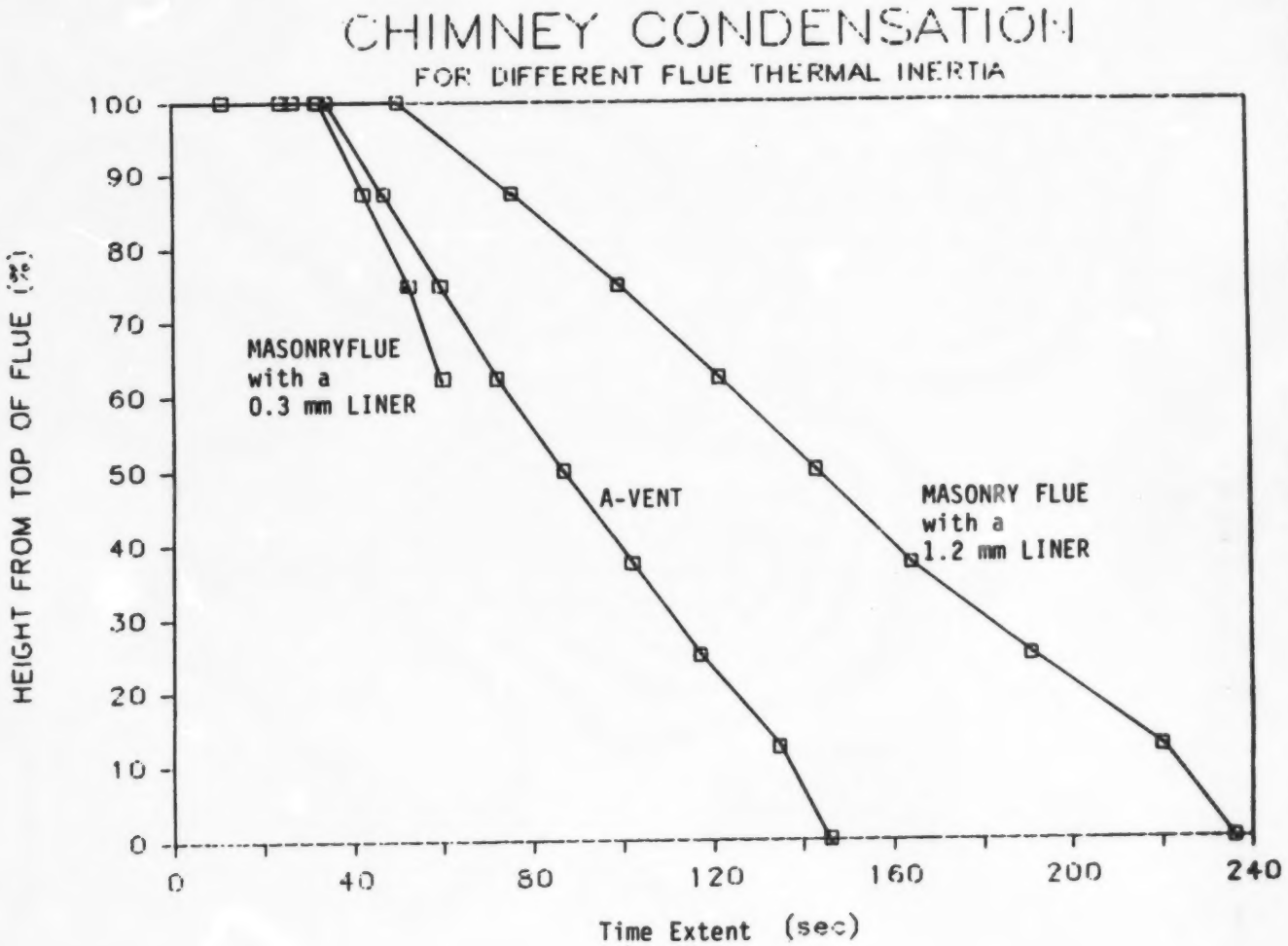

CHIMNEY CONDENSATION
FOR DIFFERENT FLUE THERMAL INERTIA
HEIGHT FROM TOP OF FLUE (%)
100
90
80
70
60
50
40
30
20
10
0
0
40
80
120
160
200
240
Time Extent (sec)
MASONRYFLUE
with a
0.3 mm LINER
A-VENT
MASONRY FLUE
with a
1.2 mm LINER

Figure 29.

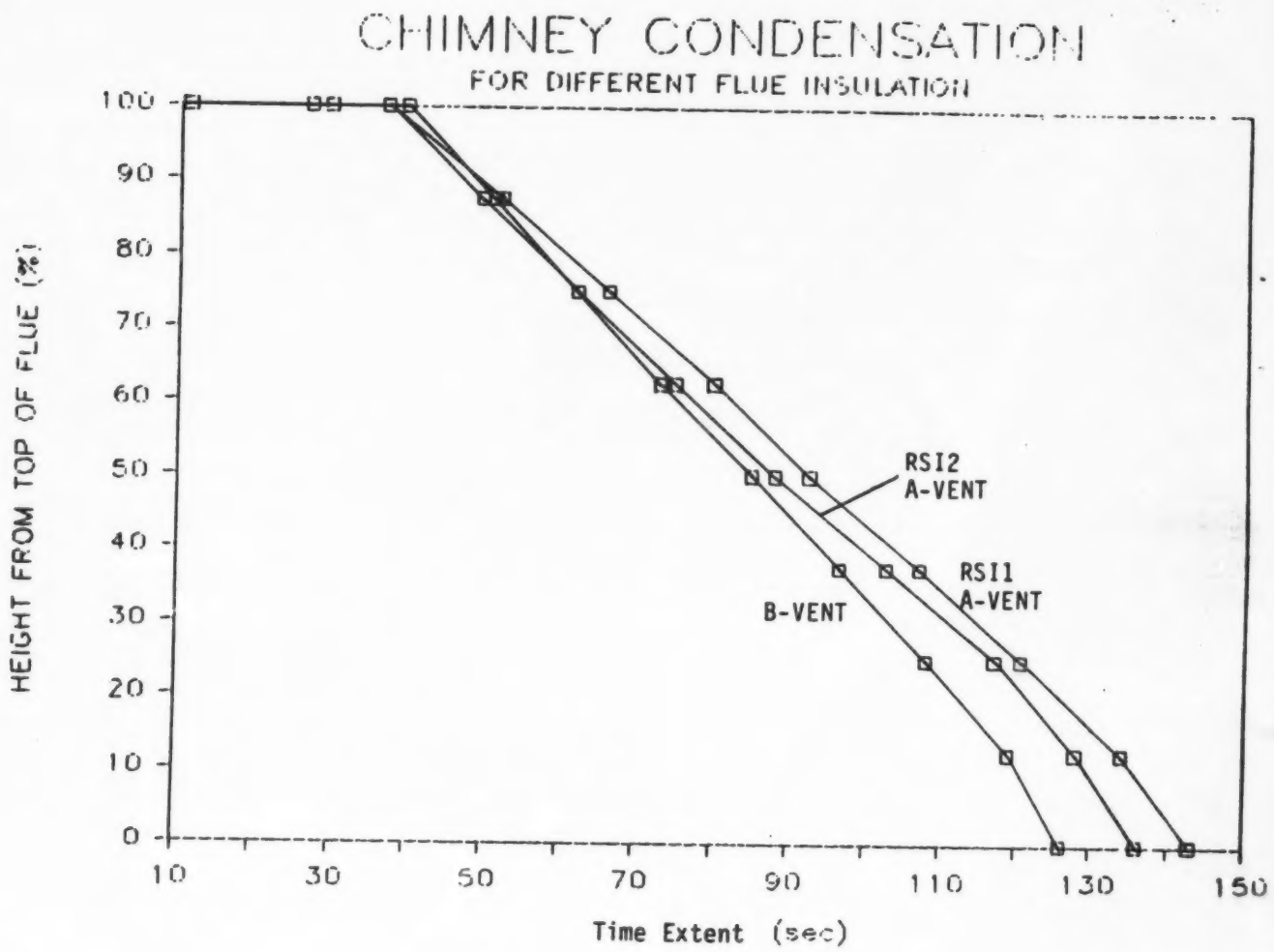

CHIMNEY CONDENSATION
FOR DIFFERENT FLUE INSULATION
HEIGHT FROM TOP OF FLUE (%)
100
90
80
70
60
50
40
30
20
10
0
10
30
50
70
90
110
130
150
Time Extent (sec)
RSI2
A-VENT
RSI1
A-VENT
B-VENT

Figure 30.

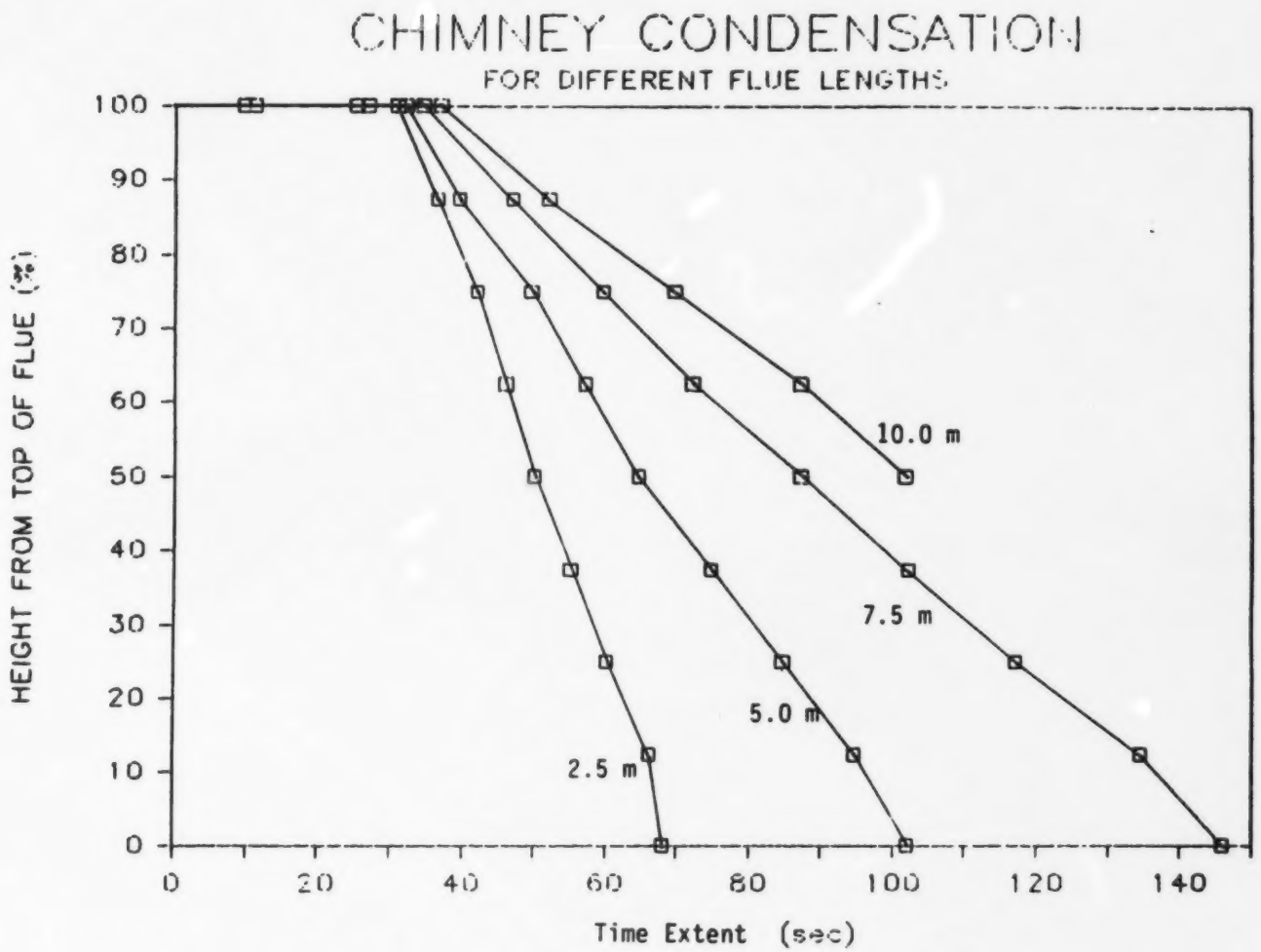

CHIMNEY CONDENSATION
FOR DIFFERENT FLUE LENGTHS
HEIGHT FROM TOP OF FLUE (%)
100
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
140
Time Extent (sec)
10.0 m
7.5 m
5.0 m
2.5 m

Figure 31.

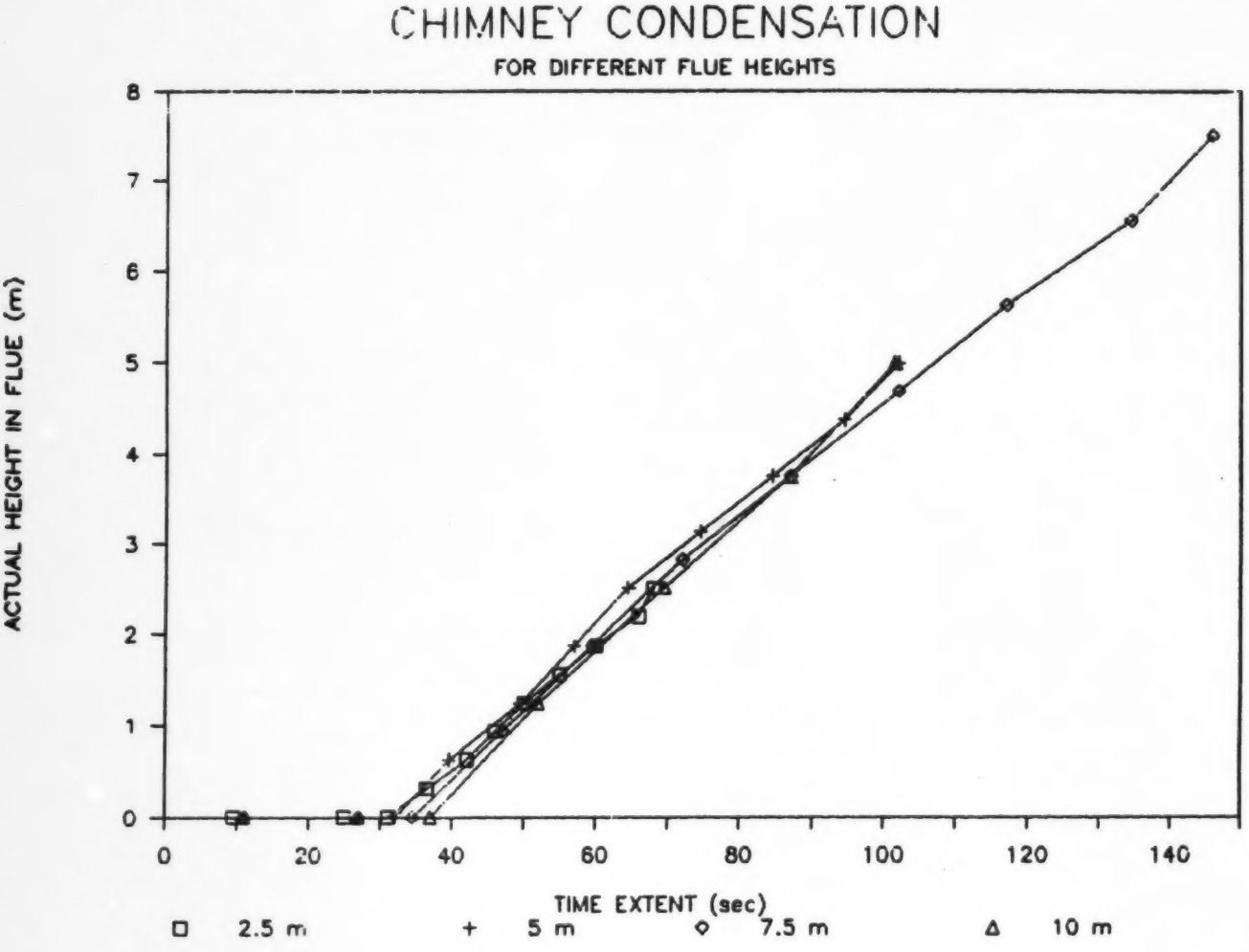

CHIMNEY CONDENSATION
FOR DIFFERENT FLUE HEIGHTS
ACTUAL HEIGHT IN FLUE (m)
0
1
2
3
4
5
6
7
8
0
20
40
60
80
100
120
140
TIME EXTENT (sec)
□ 2.5 m
+ 5 m
◇ 7.5 m
△ 10 m

Figure 32.

Figure 1. Calculation Points, Flue Elements and Dimension Reference

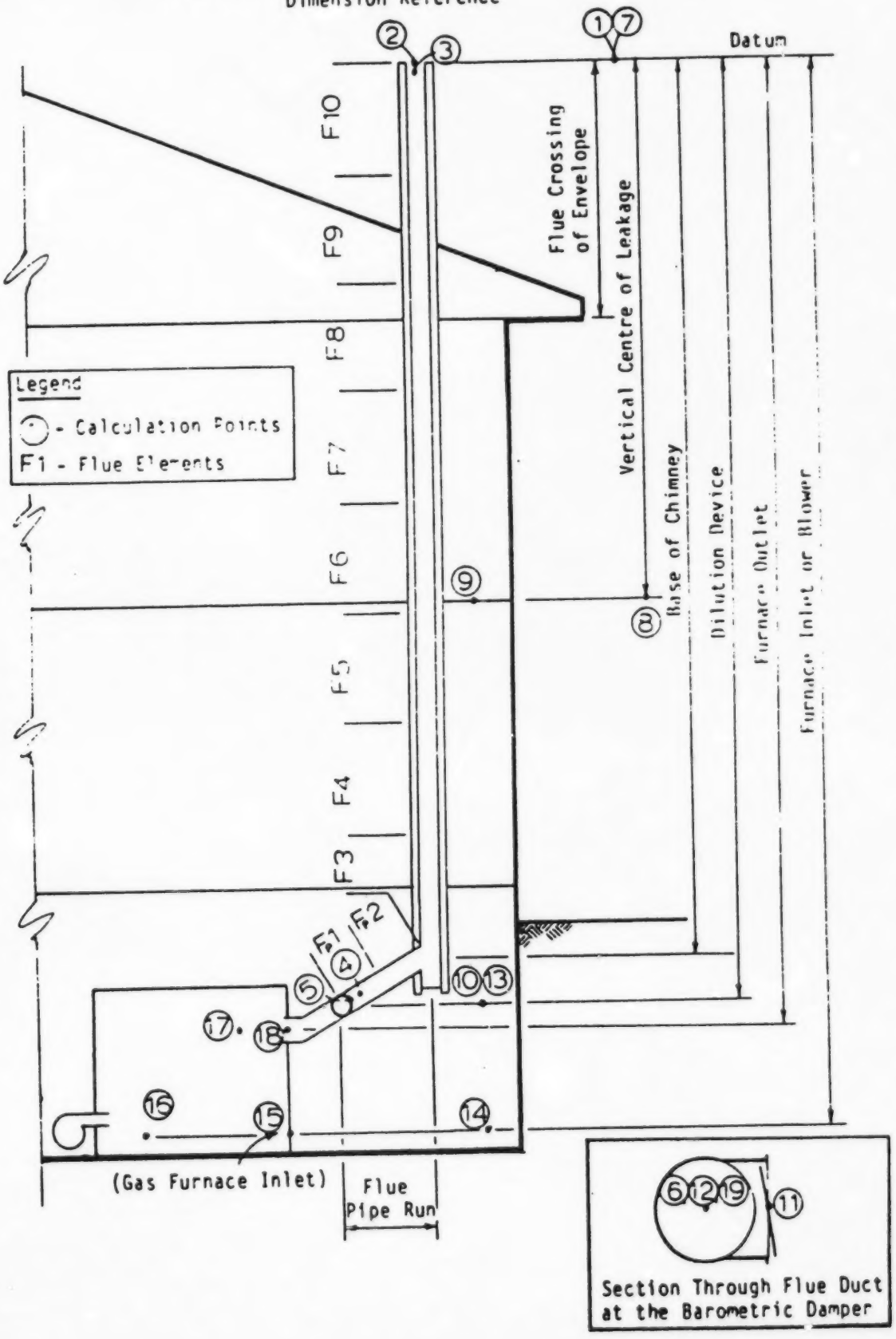


Figure 33. Condensation Elements

APPENDIX

SPECIFICATIONS OF THE FURNACE USED AND THE STANDARD 5" FLUE AND FLUE PIPE

ENVELOPE

Airtightness Characteristics: -flow coefficient: C .03050 (m3/s.Pa^n)
(as defined by standard -flow exponent: n .72
CAN/CGSB-149.10-M) (non dimensional)
Maximum Exhaust Fan Flow Rate: 0, 82.8, 136.3, 182.5 (L/s)
Maximum Fireplace Flow Rate: 0 (L/s)

AMBIENT TEMPERATURE AND WIND SPEED

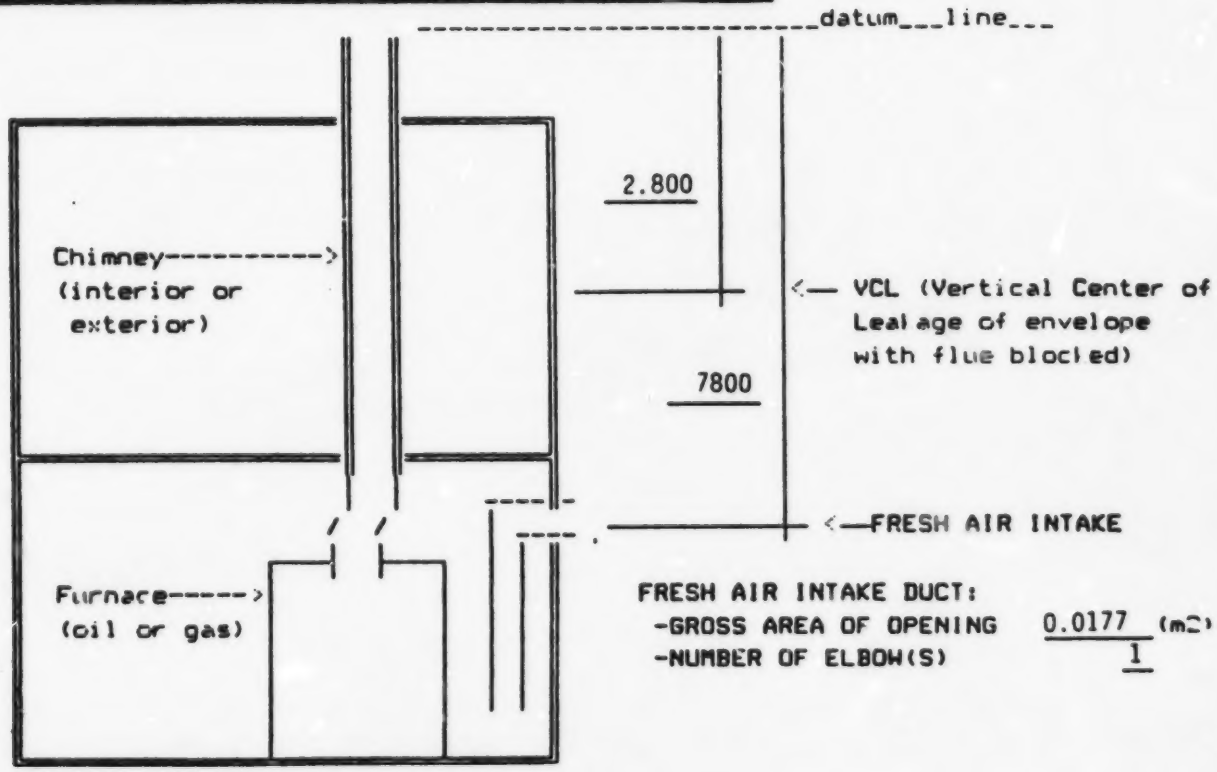
Outdoor Temperature 0.0 (C)
Indoor Temperature 20.0 (C)
Wind Speeds: -horizontal 3.0 (m/s)
-vertical 0.0 (m/s)
(up is +)

INITIAL TEMPERATURES OF ELEMENTS

Initial Flue Temperatures: -flue gas 16.5 (C)
-nodal point #1 13.5 (C)
-nodal point #2 7.5 (C)
-nodal point #3 2.9 (C)

Initial furnace temperatures: -heat exchanger surface 20.0 (C)
-stack gas 20.0 (C)

VCL & FRESH AIR INTAKE LOCATION & CHARACTERISTICS



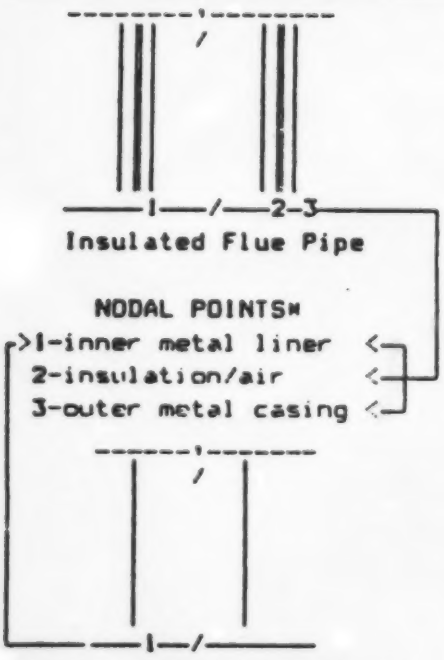
FRESH AIR INTAKE DUCT:
-GROSS AREA OF OPENING 0.0177 (m2)
-NUMBER OF ELBOW(S) 1

A-VENT CHIMNEY CHARACTERISTICS

NODAL POINTS
1-inner metal liner
2-insulation
3-outer metal casing

Open Area of the Flue	.0127	(m2)
Circumference or Perimeter		
1-inner metal liner	.399	(m)
2-insulation	.479	(m)
3-outer metal casing	.559	(m)
Element Thickness		
1-inner metal liner	.0003	(m)
2-insulation	.0254	(m)
3-outer metal casing	.0003	(m)
Densities		
1-inner metal liner	7830.0	(kg/m3)
2-insulation	384.0	(kg/m3)
3-outer metal casing	7830.0	(kg/m3)
Heat Capacities		
1-inner metal liner	500.0	(W.s/kg.C)
2-insulation	800.0	(W.s/kg.C)
3-outer metal casing	500.0	(W.s/kg.C)
Heat Loss Factors Between:		
-points 1 and 2	6.00	(W/m2.C)
-points 2 and 3	6.00	(W/m2.C)
-points 3 and surrounding	8.30	(W/m2.C)

FLUE PIPE / VENT CONNECTOR



Insulated Flue Pipe

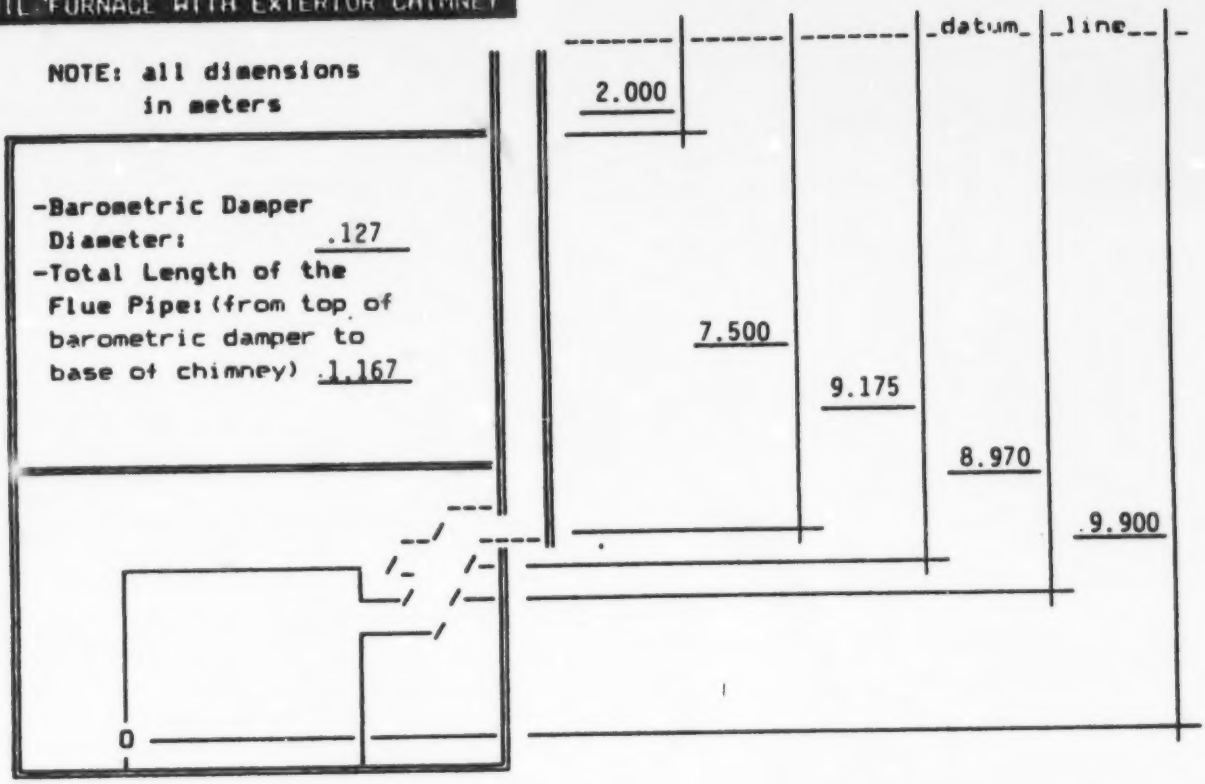
NODAL POINTS*
1-inner metal liner
2-insulation/air
3-outer metal casing

Single walled Flue Pipe*

Open Area of the Flue Pipe	.0127	(m2)
Circumference or Perimeter		
1-inner metal liner	.399	(m)
2-insulation	0.0	(m)
3-outer metal casing	0.0	(m)
Element Thickness		
1-inner metal liner	.0005	(m)
2-insulation	0.0	(m)
3-outer metal casing	0.0	(m)
Densities		
1-inner metal liner	7900.0	(kg/m3)
2-insulation	0.0	(kg/m3)
3-outer metal casing	0.0	(kg/m3)
Heat Capacities		
1-inner metal liner	500.0	(W.s/kg.C)
2-insulation	0.0	(W.s/kg.C)
3-outer metal casing	0.0	(W.s/kg.C)
Heat Loss Factors Between:		
-points 1 and 2	8.30	(W/m2.C)
-points 2 and 3	0.0	(W/m2.C)
-points 3 and surrounding	0.0	(W/m2.C)

*For single walled flue pipe enter "0" for all entries of nodal points 2 & 3.

OIL FURNACE WITH EXTERIOR CHIMNEY



OIL FURNACE CHARACTERISTICS

OPENING AREAS:	-1-firebox leakage area	.0050	(m2)
	-2-outlet (breech)	.024	(m2)
	-3-damper-full open area	.0127	(m2)
	-% of above when closed (5-100%)	5.0	(%)
OTHER DATA:	-4-interior chamber volume	.700	(m3)
	-5-heat exchanger's:-mass	61.0	(kg)
	-heat capacity	500.0	(W.s/kg.C)
	-firing rates-full on	29300	(W)
	-standby(heat source)	0.0	(W)
	-steady state efficiency	75.0	(%)
	-steady state stack gas exhaust temperature	240.0	(C)
	-furnace excess air in %	150.0	(%)